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Weather and climate information services in subsistence agriculture -farmers' experiences on the adequacy of these services in the Taita Hills, Kenya

Anni Salla

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Supervisors: Tino Johansson and Markku Löytönen

UNIVERSITY OF HELSINKI
FACULTY OF SCIENCE
DEPARTMENT OF GEOSCIENCES AND GEOGRAPHY
GEOGRAPHY

P. O. Box 64 (Gustaf Hällströmin katu 2)
00014 University of Helsinki

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tiedekunta/Osasto Fakultet/Sektion – Faculty	Laitos/Institution– Department	
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Tekijä/Författare – Author		
Anni Salla		
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Tiivistelmä/Referat – Abstract

Climate change is globally considered as one of the biggest threats to the economy and development. Agriculture is the sector that faces the heaviest consequences and agriculture is also the primary livelihood for 2.5 billion people. Especially vulnerable are those who rely on rain-fed agriculture and for them adequate information on weather and climate is essential, enabling the adaptation to climatic changes. Weather and climate information services (WCIS) which are the entity from the generation to the dissemination and utilization of the information, plays a significant role for farmers especially in the developing countries. Adequate information is accessible and accurate, also in terms of time and location, and is communicated in a way that enables using the information in practice. The connection between agricultural production and WCIS has been more acknowledged and most of the African countries are able to provide monthly and seasonal forecasts, agrometeorological forecasts and extreme weather event warnings. However, still many areas suffer from lack of information systems which would help farmers to plan their agricultural activities and to adopt better farming practices.

This study focuses on the adequacy of WCIS through farmer's experiences in the Taita Hills, Kenya. Using semi-structured interviews, it identifies ICT- and human-based sources, content, and utilization of the information and how the information is shared through social networks. Additionally, it acknowledges the role of traditional knowledge to forecast weather through indicators in the environment. Local subsistence farmers, who are the key informants of this study, have experienced the impacts of climate change mainly as delayed rain seasons and decreased rainfall as well as increased temperatures. Important weather information for the farmers, in terms of agriculture, is dominantly the information about the onset and volume of rainfall that is used to schedule farming practices to achieve successful yield.

The results of the study indicate that ICT-based information sources, such as daily forecasts from the radio, do not offer useful information for the farmers due to high uncertainty. The main sources of weather and climate information are human-based sources such as chiefs' barazas and agricultural extension officers which offer seasonal forecasts and guidance on suitable crop types and other agricultural counselling. The information is shared in a communicative way which enables a dialog between the source and the farmer. In addition to seasonal forecasts, farmers rely heavily on traditional knowledge and regard it as reliable since it is observed through own senses and has a long local history through generations. Social networks in general, including barazas and extension officers but also, for example, neighbours and farmer groups, play an essential role in sharing information. Farmers both receive and share information through several forums. However, there are still farmers that are excluded from any WCIS related social networks and hence lack capacity to adapt to climatic changes. There is still a need to develop extension services to reach everybody in need and to generate more locally accurate forecasts which require local weather data gathering. Also, there is great potential in ICT as an information dissemination tool to a large audience.

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Tiivistelmä/Referat – Abstract

Ilmastonmuutos on maailmanlaajuisesti koettu yhdeksi suurimmaksi uhaksi taloudelle ja kehitykselle. Suurimmat vaikutukset koskevat maataloussektoria mikä on pääelinkeino 2.5 miljardille ihmiselle. Erityisen haavoittuvia ovat sateesta riippuvaiset viljelijät ja heille soveltuva tieto säästä ja ilmastosta on elintärkeää, mahdollistaen ilmastonmuutokseen sopeutumisen. Sää- ja ilmastotietopalveluilla, sisältäen kokonaisuuden tiedon tuottamisesta sen jakamiseen ja hyödyntämiseen, on elintärkeä rooli viljelijöille etenkin kehittyvissä maissa. Soveltuva tieto on saavutettavaa sekä ajallisesti ja paikallisesti täsmällistä. Lisäksi sen viestinnän tulisi mahdollistaa sen hyödyntäminen. Maataloustuotannon ja sää- ja ilmastotietopalveluiden välinen yhteys on yhä enemmän tiedostettu ja suurin osa Afrikan valtioista kykenee tarjoamaan kuukausittaisia ja kausittaisia ennusteita, agrometeorologisia ennusteita sekä varoituksia äärimmäisistä sääilmiöistä. Tästä huolimatta monet alueet kärsivät puutteellisista tietopalveluista, jotka auttaisivat viljelijöitä suunnittelemaan viljelytoimintojaan ja omaksumaan parempia käytäntöjä.

Tämä tutkimus keskittyy viljelijöiden kokemukseen sää- ja tietopalveluiden soveltuvuudesta Taita-vuorilla Keniassa. Puolistrukturoitujen haastatteluiden kautta tutkimuksessa tunnistettiin teknologia- ja ihmisperustaiset tietolähteet, tiedon sisältö ja hyödyntämismahdollisuus sekä sen miten tietoa jaetaan sosiaalisten verkostojen sisällä. Lisäksi tutkimus huomioi perinnetiedon sään ennustamisesta tarkkailemalla ympäristön indikaattoreita. Paikalliset omavaraisviljelijät, jotka ovat pääosainen tietolähde, ovat kokeneet ilmastonmuutoksen seuraukset viivästyneenä sadekautena, vähentyneenä sateena sekä nousseena lämpötilana. Viljelijöille oleellinen tieto säästä on tieto sateen alkamisesta ja sateen määrä, joita käytetään viljelyn oikeanlaiseen aikatauluttamiseen ja suunnitteluun, joka taas mahdollistaa hyvän sadon.

Tutkimuksen tulokset viittaavat, että teknologiaperustaiset tietolähteet, kuten päiväkohtaiset ennusteet radiosta, eivät ole viljelijöille merkityksellisiä johtuen niiden epäluotettavuudesta. Tärkeimmät lähteet sää- ja ilmastotiedolle ovat ihmisperustaiset lähteet, kuten yhteisöjohtajien kokoukset ja maatalousvirkamiehet, jotka tarjoavat kausittaisia ennusteita, ohjeistusta oikeanlaisten viljelykasvien valinnasta sekä muuta maatalousneuvontaa. Tietoa jaetaan kommunikoiden, joka mahdollistaa dialogin tietolähteen ja viljelijän välillä. Kausittaisten ennusteiden lisäksi viljelijät hyödyntävät perinnetietoa ja kokevat sen luotettavaksi, sillä se koetaan omin silmin ja lisäksi perinnetiedolla on pitkä paikallinen historia läpi sukupolvien. Yleisesti ottaen sosiaalisilla verkostoilla, kuten yhteisöjohtajien kokouksilla ja maatalousvirkamiehillä, mutta myös esimerkiksi naapurilla ja viljelijäryhmillä on suuri rooli tiedon levittämisessä. Viljelijät sekä vastaanottavat että jakavat tietoa monilla foorumeilla. Siitä huolimatta on kuitenkin viljelijöitä, jotka ovat kaikkien sää- ja ilmastotietoa jakavien verkostojen ulkopuolella ja heillä on heikko kapasiteetti sopeutua ilmastonmuutokseen. Vielä on tarve kehittää maatalouspalveluiden tarjontaa saavuttamaan kaikki sitä tarvitsevat sekä kehittää ennustusten tarkkuutta paikallisella säädatalla. Lisäksi teknologiassa on runsaasti potentiaalia tiedon levittämisessä suurille määrille viljelijöitä.

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List of abbreviations

ASAL	Arid and Semi-Arid Land
CA	Conservation Agriculture
ENSO	El Niño Southern Oscillation
GCM	Global Climate Model
GDP	Gross Domestic Product
GoK	Government of Kenya
GHG	Greenhouse gas emissions
KMS	Kenya Meteorological Services
KNBS	Kenya National Bureau of Statistics
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
MoALF	Ministry of Agriculture, Livestock and Fisheries
MDG	Millennium Development Goals
ND-GAIN	Notre Dame Adaptation Initiative
NGO	Non-Governmental Organization
NWP	Numerical Weather Prediction
OECD	Organization for Economic Co-operation and Development
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
SDG	Sustainable Development Goals
SRES	Special Report on Emissions and Scenarios
TK	Traditional Knowledge
UHI	Urban heat island
UN	United Nations
UNDP	United Nations' Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
WCIS	Weather and Climate Information Services
WCS	Weather and Climate Services
WRI	World Resource Institute

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1 Introduction

According to a survey by Pew Research Centre, climate change is regarded as the world's biggest threat. Half of the 26 countries in the survey listed climate change as the top concern and the worry about the impacts of climate change to the security of the nations has risen (Pew Research Center 2019). IPCC's (Intergovernmental Panel on Climate Change) reports on climate change have received more recognition and movements around climate change mitigation and adaptation have been more and more visible in the media all over the world both within the civil society and on the governmental level. The impacts of climate change are, however, already experienced especially in the developing countries which will also face the most severe impacts. Climate change threatens global sustainable development which would be a challenge even without the effects of changing climate (World Bank 2010.) Climate change is considered in the UN's Sustainable Development Goals specifically in Goal 13 which calls for urgent actions on climate change and the impacts of it. The targets of this goal are to strengthen resilience and adaptive capacity, to integrate climate change to national policies, to improve education on climate change mitigation and adaptation, emphasize the role of the developed countries and to support the developing countries (UN 2019.)

Particularly vulnerable to the impacts of climate change are rural areas where people rely on rain-fed agriculture. Reliance on rainfall without access to irrigation poses even more severe risks for the livelihood and these subsistence farmers lack in assets to deal with the consequences of climate change. While the climatic circumstances change, farmers need accurate and timely information to be able to adapt to these changes. Adequate information, in terms of availability, accuracy and time, on expected weather conditions as well as knowledge and skills to adapt to the changing climate is essential. The need for such information has been acknowledged and availability of weather and climate change information services has increased. However, there are still several constraints in access and utilization of this information. It is not self-evident that information reaches those who are the expected target users of it or that the users are able to utilize that information. This includes, for example, aspects in the content of the information such as accuracy and locality as well as factors in the process of communication of the information.

This research was carried out in the Taita Hills in Kenya with an aim to find out what kind of weather and climate information services are available for the subsistence farmers and is the information serving their needs to have successful crop yields to maintain their subsistence agriculture livelihoods. The objectives of this research are to identify technology and human-based information sources, the nature of the information, and how the information is used by the respondent farmers. The studied variables and components of information include, for example, the aspects of timely information and locality as well as how the information is communicated for the farmers. The study also assesses the role of traditional weather knowledge and how such knowledge is used.

This study first describes the background of the research by outlining what kind of effect agriculture has on global and national development and focuses on climate change as a phenomenon and its impact on development and agriculture. Then the study presents the theoretical framework by creating an understanding of weather and climate information services, the role of such services in agriculture and also familiarizes with traditional knowledge in the context of climate and agriculture.

The latter part of this study describes the case study area, the Taita Hills, and also creates a view on the effects of climate change in that local context and what kind of weather services are available in Kenya. The results of his research are sectioned according to the type of weather and information source and the application of the received information. The last part provides conclusions and discusses some of the aspects that were found to be relevant in terms of weather and climate information services. From the personal perspective of the author, this research draws from the interest in rural development in developing countries and the aspect of capacity to utilize available information and skills.

2 Background

The focus of this research is on subsistence farmers who practice rain-fed agriculture and hence are exceptionally vulnerable to the impacts of climate change. Therefore, this chapter firstly, outlines a background for this research by explaining the role of agriculture in development and, secondly, focuses on what kind of effects climate change has on development and agriculture, thus creating a basis for this study.

2.1 Agriculture and development

According to FAO (2016), 2.5 billion people have agriculture as their main source of livelihood and these people who are practicing small-scale farming, herding, fishing or are in forest-dependent communities produce more than half of the agricultural production globally. Additionally, according to the World Bank (2019a), in 2016 65 percent of the employed working adults received their main income in the agricultural sector, and in 2014 was estimated that agriculture as a whole covered one-third of gross domestic product (GDP) globally. Hence, agriculture plays an essential role both for individuals as well as for the global economy.

Agriculture has great significance in United Nations' Sustainable Development Goals. Regardless of the fast global economic development, 820 million people are still suffering from chronical undernourishment, and to feed the global growing population agricultural production will have to increase approximately fifty percent by 2050. Goal 2 "Zero hunger" is set *to end hunger, achieve food security and improved nutrition and promote sustainable agriculture.* Additionally, agriculture is in connection with several other goals: for example, approximately 75 percent of the extreme poor live in rural areas and depend on subsistence farming, development in agriculture sector creates jobs and decreases hunger, thus contributing to ending poverty and good health and well-being (Goal 1, Goal 3). Also, the majority of child labour takes place in agriculture, this can be changed by supporting schools' food programmes and integrating seasonal agricultural work and school curricula (Goal 4). Gender plays an important role since half of the labour force in the agricultural sector in the developing countries are women, yet women lack access to resources such as land and financial assets. Equality in such issues leads to long term positive economic and social results (Goal 5). Agriculture works both as a driver for climate change and also faces the most severe impacts of climate change but at the same time, it can also be part of the solution (Goal 13). Among the mentioned connections with the Sustainable Development Goals agriculture can have an impact in achieving any of the them and this emphasizes the role of agriculture sector in global development and wellbeing not only in terms of decreasing hunger and poverty but also for example in peacemaking by supporting food security and livelihoods of rural communities that are the most affected in conflicts (FAO 2019.)

2.2 Impacts of climate change

Climate change is currently and increasingly affecting people's lives, disrupting ecosystems and degrading economies all over the world. Since climate change is a global phenomenon, it is important to outline how the scientific community understands the functioning of the climatic system, as the causes and effects of climate change. Additionally, this section focuses on the impacts of climate change on development and on the agricultural sector as it is in the centre of this research. Understanding the functioning of the climatic system and the effects on development and agriculture also highly contributes to the generation of information on the experienced and expected changes in climate and how nations, societies, and individuals can adapt to those changes.

2.2.1 Evidence and causes of climate change

Intergovernmental Panel for Climate Change (IPCC) defines climate change as a change in climate properties which can be identified by the means and/or variables. It is a long-term change, technically meaning a duration of decades or longer. Additionally, the changes can be a cause of both human activity and natural causes. United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as only caused by human activities (IPCC 2007.)

Both natural and anthropogenic factors and processes contribute to the Earth's energy budget and, hence, are potential drivers for climate change. The strength of the drivers is defined as radiative forcing and it is the change in the energy flux induced by them. Greenhouse gas emissions, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), in the atmosphere, have greatly increased since the pre-industrial era. For example, the cumulative CO_2 emissions in the atmosphere were 2040 ± 310 $GtCO_2$ and approximately 40 percent of this CO_2 has remained in the atmosphere, the rest is absorbed in the land and in the sea. Approximately 50 percent of the CO_2 emissions between a period of 1750 to 2011 took place during the last 40 years and the greenhouse gas emissions have continued to grow between 1970 and 2010, especially during the last 10 years. Carbon dioxide emissions have played a significant role and such emissions, mainly from the use of fossil fuels and industrial processes, covering approximately 78 percent of the total greenhouse gas emissions between 1970 and 2010. The main contributors to these increases are global population growth and economic development. According to IPCC, it is extremely likely that more than 50 percent of the observed rise in global surface temperature between a period of 1951 and 2010 is a result of the anthropogenic induced increase in greenhouse gas emissions and other anthropogenic forcings. Anthropogenic factors have likely contributed also to the changes in global water systems since 1960 and to retreat of glaciers and ice sheets (IPCC 2014a: 44-48, 126.)

According to IPCC's Fifth Assessment Report, each of the last decades has been warmer than any preceding decade since 1850. During the period from 1880 to 2012, combined land and ocean surface temperature has increased 0,85 °C and surface warming is experienced all around the globe. It is evident that the tropospheric temperature has increased since the mid-20th century (IPCC 2013: 5.) Ocean, the upper 75 m, has warmed by 0,11 °C per decade from 1971 to 2010. Additionally, in ocean regions with high salinity, the saline rate has increased and in regions with low salinity, the rate has decreased due to changes in evaporation and these changes again have affected the global water cycles. Also, from 1901 to 2010 global sea level have risen by 0,19 m as a result of shrinking glaciers (IPCC 2014b: 40-42.)

IPCC has identified five integrative reasons for concern to outline climate change induced risks across sectors and regions. First one is the risk generated on unique and threatened ecosystems; second is extreme weather events such as heatwaves and flooding; third is uneven distribution of impacts since disadvantaged people and communities face greater vulnerability; fourth is global aggregate impacts referring to extensive biodiversity loss and loss of ecosystem goods and services; the last and fifth one is large-scale singular events as some ecosystems may experience irreversible changes (IPCC 2014b: 30.)

2.2.2 Impact on development

Climate change has a great influence on global development. Societies have always been dependent on climate, for example, due to its role in agricultural production, and at the same time, human actions with increased greenhouse gas emission since the industrial revolution have had an influence on the climatic system. Therefore, climate affects development and development affects climate. Without interference, climate change will affect the development progress and endanger the well-being of future generations. Although the impacts of climate change are and will take place around the world, the developing countries will face the most severe effects such as drought and other extreme weather events. Additionally, the developed countries have been the main recipients of the benefits of the carbon-intensive development. Sustainable development, socially, economically and environmentally, is a challenge even without climate change. Growth without attention to the protection of the environment does not reduce poverty and inequality (World Bank 2010: 39-40.)

According to the Millennium Development Goal (MDG) Report 2015, between the years 1990 and 2015 extreme poverty has decreased from 1.9 billion to 836 million. Between the same period, the number of undernourished people in developing countries has decreased by almost half. Death rate of children under five years olds has decreased globally from 12.7 million to 6 million regardless of the population growth in the developing countries. In 2015, 91 percent of the global population is using improved drinking water sources which is a 15 percent increase since 1990. Additionally, terrestrial and marine protected areas have increased in many regions (UN 2015: 4-5, 7.) Regardless of the achievements in the development objectives, progress has been uneven between regions and countries. Poorest and otherwise disadvantaged people inhabit areas that experience the most severe impacts of climate change while they also lack in assets to cope with the changes and risks. Livelihoods of poor people are also more connected to the natural resources as they usually live in areas suffering more from environmental degradation. This creates a challenge for the global development (UN 2015: 8.)

Climate change poses a risk for many sectors and productive environments, such as energy, forestry, coastal zones, and agriculture, which will be discussed more in the following chapter, both in developing and developed areas. Developing areas are more at risk, partly due to extreme weather events and due to low adaptive capacity. Climate change, especially warming of average annual temperatures, can potentially have a great influence on the level and growth of gross domestic product (GDP), especially in poor countries. According to IPCC's Synthesis Report from 1995, anomalously warm years are expected to decrease the current level, and also the subsequent growth rate of GDP in developing countries (IPCC 1995: 15; World Bank 2010: 40.)

Climate change has an effect on human health as well. The effects are both direct and indirect. Direct effects such as extreme heat and results of extreme weather events affect people especially in areas such as coastal zones and cities with high and dense populations and especially in the developing world with insufficient health care systems. Indirect effects are consequences of changes in the environment and in the insect and rodent populations which may lead to parasitic diseases and increased crop damages which reduces especially subsistence farmers' food security. Rising temperatures will expose more people to diseases such as malaria and dengue with the emphasis on the developing world. Malnutrition caused by decreased agricultural production can lead to weaker resistance to diseases (Reid 2014: 81-.87; World Bank 2010: 41.) Higher occurrence of diseases and malnutrition may potentially lead to weaker work capacity which consequently lowers agricultural production even more. This may restrict people's, especially subsistence farmers', ability to manage with their livelihood, and disease and malnutrition induced disabilities can also restrict a person's ability to seek for information on suitable adaptation measures.

As the world is already experiencing water stress, climate change induced warming functions as an exacerbating factor affecting rainfall patterns, river flows, and lake and groundwater levels. Whereas some areas are experiencing increased water depletion, other areas are facing floods. Most of the global population are settled along coastal zones, wetlands and river basins, and climate change affects these areas' conditions to provide water supply. Sustainable development and wellbeing of the ecosystems are endangered when the quality and quantity of water reduces affecting, for example, power generation and irrigation. Also, water quality can be reduced when reservoirs and river water level decreases affecting sewage and industrial wastewater. This reduces the amount of water for domestic use as well. It is estimated that a great part of the global population will face chronic or absolute water shortage as a result of climate change together with the growing population. Societies will likely face great challenges in responding to the changing water availability and quality (Reid 2014: 55-56, 61; Schewe et al. 2014.)

Approximately two billion people do not have access to electricity especially in rural areas and providing electricity to those areas is a challenge. Compared to urban areas with high population density, it is relatively costly to provide energy to rural areas with low population density. Access to energy improves people's possibilities to educate themselves and have access to health services and livelihoods and hence improves the ability to cope with the consequences of climate change. Access to technological information sources, for example to smartphones and radio, requires electricity. In Kenya, 75 percent of the population had access to electricity in 2018. Kenya has also developed Kenya National Electrification Strategy (KNES) which aims to provide electricity to all citizens by 2022. When talking about energy production it is important to note that the energy sector plays a significant role in climate change. For example, burning of fossil fuels contributes to the largest share, approximately 60 percent, of all greenhouse gas emissions and even 80 percent of the CO_2-emissions. Two-thirds of that 80 percent come from energy/heat generation and transport, 13.60 $GtCO_2$ and 8.94 $GtCO_2$ respectively. Therefore, solving these challenges requires inputs to sustainable energy sources. Kenya is the largest producer of geothermal energy in Africa and geothermal energy provides the largest share for electricity, followed by hydro and oil. (IEA 2019a; IEA 2019b; IEA 2019c; Reid 2014: 88-89; World Bank 2018; World Bank 2019b.)

Urban areas contribute to climate change by being clusters of social and economic activities that are based on the combustion of fossil fuels. Greenhouse gas emissions from urban areas represent 40-70 percent of global GHG emissions. Over half of the global population is already living in cities and the majority of the population growth will be in cities, especially in developing countries. This will significantly increase the energy demand in urban areas and most of the increase will be in developing countries. While urban growth is a driver for climate change, a lot of people living within those areas are vulnerable to the consequences of climate change. Climate change induced impacts are floods, storm surges, sea level rise and temperature extremes contributed, for example, by urban heat islands (UHIs) which are caused by low coverage of vegetation, low evapotranspiration and high coverage of surfaces with low albedo. Challenges in urban areas are further increased due to rural-urban migration when rural poor migrate to cities as a result of climate change impacts (Mohajerani et al. 2017; Un-Habitat 2011: 91; Reid 2014: 190-192.)

Climate change is a significant driver for migration and displacement, potentially even more than war or political insecurity. A great number of people have already been forced to leave their homes due to sudden-onset climate related hazard, such as floods and storms, or due to slow-onset hazards, such as drought or sea level rise. Migration can take place on different scales from rural-urban migration to migration to other countries. Estimations on the quantity of climate change induced movements of populations vary between 200 million to a billion people by 20150 (Opitz Stapleton et al. 2017: 9-10; Reid 2014: 210-213.) Climate change induced migration may occur, both rural-urban and to other regions and countries, as well as permanent and temporary, when there is no capacity to implement other climate change adaptation measures (McLeman & Hunter 2010.) Knowledge on the expected effects of climate change and suitable adaptation methods could decrease the need to migrate if a person is able to keep his/her livelihood, especially subsistence farmers who are dependent on the production of the land.

2.2.3 Impact on agriculture

Agriculture is one of the sectors which faces the heaviest impact of climate change (World Bank 2010). According to The World Food Programme, the number of people at risk of malnutrition by 2050 will be 10-20 percent higher as a result of climate change as would be without it, especially in Sub-Sharan Africa (Parry et al. 2009: 68). The impacts of climate change on agriculture and human well-being can be presented in three categories: biological impacts on yields; resulting impacts on prices, production and consumption; and impacts on calorie consumption. Climate change induced effects, such as rising temperature and changing rainfall patterns, affects crop yields directly and through changing water availability indirectly. Crops that are rain-fed are affected by changes in precipitation and temperature while irrigated crops are affected by changes mainly in temperature. However, irrigated crops are affected by reduced water availability for irrigation activities (Nelson et al. 2009: 4-5.) While both rain-fed and irrigated crops are affected by climate change induced lack of water, farmers need information on how to cope with the situation. If irrigation is not possible from natural water sources, springs etc., farmers are forced to shift their agricultural practices more suitable for drier conditions. Additionally, rainwater harvesting, which is a common practice in Kenya in low and medium potential agricultural land, is an adaptation option for drier environmental conditions (Mendez & Paglietti 2015).

Global prices can be used to indicate the impacts of climate change. Even without the effect of climate change crop prices would increase during the period from 2000 to 2050 due to population growth, rising living standards and biofuel use. The estimated increase of price for rice is 62 percent, maize 63 percent, soybean 72 percent, and wheat 39 percent. The impacts of climate change will raise those figures even more with a 32-37 percent increase for rice, 52-55 percent for maize, 94-111 percent for wheat and 11-14 percent for soybean. Use of fertilization has a 10 percent effect on each. Increasing crop prices result also in livestock through increased feed costs. Crop production, in general, is affected by changes in yield directly and by farmer's adaptation measures on prices such as changes in crop type and inputs. Sub-Saharan Africa and South Asia will face the most prominent impacts. Sub-Saharan Africa will potentially face a 15 percent production decrease in rice, 34 percent in wheat and 10 percent in maize (Nelson et al. 2009; 6). Schlenker & Lobell (2010) have estimated 8 – 22 percent yield losses by 2050 in maize, sorghum, millet, groundnut and cassava which are the main staple crops in Africa. While meat consumption raises along with the raising living standards globally, climate change induced heat waves and diseases may affect meat production, which is a significant contributor to the greenhouse gas emissions (Nelson et al. 2009: 6)

While climate change affects agricultural production through changes in rainfall patterns and temperature, it also contributes to the distribution of animal and plant diseases and pests. Changes in temperature and moisture can enhance the generation of harmful plants, fungi, and insects while the overall natural habitat changes and affects their host and natural enemies. Changes in the environment also affect animals' and plants' resistance to pests and diseases. Increased occurrence of pest damages affects agricultural production, which affects the quantity and quality of food available and endangers their livelihood (FAO 2008.) Subsistence farmers in developing countries who lack resilience to climatic and environmental changes are vulnerable to yield and livestock losses caused by pests and diseases. These farmers also have limited possibilities to cope with such outbreaks if they lack in financial or technical assets or knowledge.

2.2.4 Approaches to climate adaptation

Adaptation to climate change can be defined in several ways and, for example, Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC) and United Nations Development Programme (UNDP) all have their slightly different definitions. Adaptation can be seen as adjustment, practical steps, process or outcome and, hence, it can create different kinds of expectations depending on the used term (Levina & Tirpak 2006.) According to UNFCCC, adaptation is ecological, social or economic adjustments to expected or already experienced changes in climate and its impacts. It is modifying practices, processes and structures to correspond with the expected damages or to potentially benefit from the outcomes of climatic changes. Type of adaptation strategy depend on the context and varies between communities, businesses, organization, and regions (UNFCCC 2019.)

Dessai et al. (2005) have identified three groups of adaptation approaches. The first group represents IPCC's approach which is heavily dependent on climate change scenarios since they are the factors from which the actual adaptation strategy is derived from. The second group is risk approaches which aim to identify and reduce risks to humans and to ecosystems. These approaches focus on the management of uncertainties which can be followed by determination and reduction of the event. Climate scenarios function as tools to examine the causality between climate change and the event. The third group of approaches is the human development approaches which focus on the aspect of vulnerability. These approaches aim to improve adaptation to reduce vulnerability which they see as a key action to reduce the impacts of climate change. Vulnerability can be seen as a result of both climatic and non-climatic factors.

There are also other types of approaches and options for climate change adaptation. Low-regret (also known as no-regret) option bring benefits even without the impacts of climate change and action related are relatively low. Examples of low-regret adaptation strategies in agriculture are, for example, development of resistant crops and, depending on the current situations, developing crop insurance and irrigation systems. Win-win options bring positive results by minimizing impacts of climate change but bring also other positive results, for example, social or economic benefits. Initiative for win-win strategies may come from other needs or will than a need to adapt to climate change but it may bring adaptation benefits at the same time (Hallegatte 2009; Willows & Connell 2003: 67.)

Ecosystem-based climate adaptation strategies aim to reinforce the adaptive capacity of ecosystems to prevent risks. These strategies often have very low costs and can bring other benefits as well. Reversible (also flexible) strategies aim to minimize the cost of having a wrong climate scenario in use. An example of this strategy is early warning systems that can be readjusted annually. Safety margins-strategies include safety margins in new investments for ensuring that responses are resilient enough for a variety of changes in the future, for example, drainage systems in cities can be designed to handle more water than is needed at that moment. Soft adaptation strategies are other than technical solutions, for example, institutional or financial measures. Institutional capacity building is soft adaptation. Reducing decision-making time horizons strategies promote shifting to a shorter time scale, for example, in terms of faster production in forestry using species that have a shorter rotation time. Lastly, sometimes it might be worthwhile to delay any adaptation actions if they would not bring any benefit (European Commission 2014: 8; Hallegatte 2009; Willows & Connell 2003: 67.) Some of these adaption strategy types are overlapping with each other meaning that one strategy can be categorized as more than one type.

Regarding agriculture, there are different levels where adaptation measures can be taken. On a practical level, several changes and modifications can be made in cropping systems, for example, changing to other crop types that are more suitable for the new climatic conditions such as fast-maturing crops or crops that are resistant to heat shocks and drought. Also, changes in time or amount of irrigation is a potential adaptation strategy as well as rainwater harvesting and effective water management in irrigation. Changing the timing or location of agricultural activities and improving resistant to pests and diseases are also a potential response to climatic and environmental changes. Livelihood diversification, as combining different farming activities such as cropping and livestock raising, as an adaptation strategy, minimizes income losses. Also, using weather and climate forecasts can be used to minimize losses if agricultural practices are modified according to the expected weather and climate conditions (Howden et al. 2007.)

Kenya's National Adaptation Plan 2015-2030 aims to enhance country's long-term resilience and adaptive capacity with actions that relate with the economic situation and country level vulnerabilities. The agricultural sector specific long-term action is to promote and implement climate smart agricultural practices in Kenya through, for example, generation and promotion of climate change related information on agriculture which is relevant in terms of this research, promotion of drought tolerant traditional crops, water harvesting, weather insurances, conservation agriculture, agroforestry, and integrated soil fertility management. This is done through numerous projects, programmes, strategies and initiatives (GoK 2016: 1, 37.) One government driven strategy is Kenya Climate Smart Agriculture Strategy 2017-2026 which has defined three strategic issues in adaptation. It firstly, recognizes provision of accurate, timely and reliable weather and climate information, promotion of drought resistant crop varieties and diversification of livelihoods as tools to cope with vulnerabilities as a result of changes in temperature and precipitation. Secondly, recognizes development of effective early warning systems and disseminating downscaled weather information as tools to reduce vulnerability to extreme weather events. Thirdly, it recognizes promotion of water harvesting and sustainable management of natural resources as tools to reduce vulnerability as a result of unsustainable natural resource management (MoALF 2017a: 57-58.)

3 Theoretical framework

This chapter, firstly, concentrates on the definition, content, and use of weather and climate information, and how such data and information is formulated, what is the meaning of such information in agriculture and, also, considers the importance of traditional weather knowledge.

Secondly, this chapter focuses on the communication aspect in weather and climate information by theorizing the concept of access, different communication processes and different components in such processes, i.e. this second section focuses on the dissemination of weather and climate information.

3.1 Conceptualizing weather and climate information

This chapter focuses on the generation of the information that at the end is potentially used by the target farmers. In this study information on weather and climate is divided into two sections. The first one is weather and climate information services (WCIS) that result from scientific modelling. This includes weather predictions, forecasts, climate modelling, and climate scenarios, and in this case also information on adaptation measures, how this information is transferred to the users and utilization of such information. The second is traditional knowledge (TK) which is mostly orally transmitted methods to predict weather from generation to generation. This research pays attention to the different weather indicators in the environment and how this information passes on from people to people within society.

3.1.1 Defining climate and weather information services

In scientific literature information on weather and climate and the transfer of such information for users is defined as weather and climate information services (WCIS) or weather and climate service (WCS) (Georgeson et al. 2017: 1; Vaughan et al. 2019: 2). In this research, the term weather and climate information services (WCIS) are used focusing on the dissemination and use of information. This research also uses both *climate change information* and *climate information* as synonyms since all climatic issues in this context deal with changes in climate.

In order to execute appropriate adaptation practices, relevant climate change information is essential. It includes meteorological data but also non-climate related information. Climate change information is needed by several groups from national governments to sectoral officials, water managers and small-scale farmers who are the target group and the key informants of this research. Comprehensive adaptation requires a transfer of information from the national level to the local level and vice versa and also across different ministries and communities. The key questions regarding climate change information are what kind of data and information are needed and how such information is collected and disseminated (WRI et al. 2011: 48). Hansen (2002), has identified attributes of successful use of weather forecasts and includes also the aspect of time, namely when the information is available to the end-users. In order to use the forecasts efficiently, the user needs the information at the right time with enough time to prepare any needed procedures.

World Resources Institute (WRI) has identified several requirements for effective and adequate climate change information. Such information should be user-driven considering cultural differences securing feasibility for all levels in the society. Information should also be sufficient in scope and scale in a way that it is easily applied for planning and policymaking and accurate enough to support assessments of risks and vulnerability. Frequent updates and costs-effectiveness are required. Additionally, information should be accessible for everyone who needs it and also target specific (WRI et al. 2011: 50.) The last requirement point is in the centre of this research since the target group of the research is those who need climate change information for practical adaptation actions. Also, the first point is relevant when considering this study since the target group represents a specific cultural group and a specific social group.

As mentioned above, both climate related information and non-climatic information are needed to provide comprehensive and usable information for adaptation purposes. Decision-makers on the national and international levels need such information for adequate targeting and prioritizing and to transform the information into a usable form for the community level to be used. Non-climatic information should include data from social and economic systems, institutions, stakeholders, physical infrastructure and ecosystem. Climatic information includes historical information which is for tracking trends and used in forecasts; real-time observations which are beneficial especially in extreme event situations; and forecast of weather and climate conditions and changes that are specially used for planning future decision making and measures. However, according to WRI, daily and seasonal forecasts have limited accuracy and such uncertainties hinders especially longer forecasts although long term projections have improved during the time. Local projections are still less certain while global models are more coherent (WRI et al. 2011: 51-53.)

Climate scenarios are representations of future climate and used for identifying and explaining the impacts of climate change. Generally, scenarios are used in situations that have uncertain outcomes. Emission scenarios aim to explain the human contribution to future climate with several factors such as population growth and economic development pathways. IPCC has used several climate scenarios in the Assessment Reports. The Third and Fourth Assessment Reports used SRES (Special Report on Emissions and Scenarios) in 2000 which are based on changes in population, economic development, and energy use. For the Fifth Assessment Report, the scientific community developed RCPs (Representative Concentration Pathways) which consider the information needs of the policymakers and different approaches to achieve climate change related targets. RCPs take into account changes in gases and pollutants as CO_2, methane, nitrous oxide, fluorocarbons, sulphur dioxide, soot, organic carbon, carbon monoxide, nitrogen oxide, VOCs and ammonia. RCPs consist of four pathways of which RCP8.5 has a rising radiative forcing pathway, RCP6 has stabilization without overshoot pathway, RCP4.5 has stabilization without overshoot pathways and RCP2.6 has a peak in radiative forcing and then a decline (Quante & Bjornes 2016: 515-522; van Vuuren et al. 2011: 12.)

Climate models are for understanding and predicting climatic annual, decadal and centennial changes. Global climate models (GCMs) are mathematical representations of the major climate system components, atmosphere, land surface, ocean and sea ice, and their interactions. The spatial resolution varies between different models. Data can be downscaled dynamically or statistically for creating finer scale models. Dynamical downscaling is derived from GCMs to create a higher resolution Regional climate model (RCM). Statistical downscaling is based on GCM as well but is a two-phase process, first, an empirical relationship between local climate variables is developed and this data is then applied to the GCM (Flato et al. 2013: 746-748.)

Weather forecasts are short term information about precipitation, temperature, and wind. Predicting future weather is divided into three approaches. Point forecasting utilizes information on historical time and creates a correlation between the present and the future. Pattern forecasting is based on observations and the movements of pressure patterns. The third, numerical weather prediction (NWP) is the foundation of modern weather forecasting and based on the application of computer models and mathematical equations that describes atmospheric changes. NWP starts from a large number of observations, hence fast communication is needed to gather the information and efficient computers to run the data and calculations. After the observation capture, the data is assimilated by computer modelling that is able to simulate the atmospheric behaviour. Weather predictions are derived from these modellings. Due to the effects in water's state of matter, Earth's rotation and topography, the calculations are generalized for a certain size of blocks, 20 km across for global predictions and 2 km across for local national level predictions. Predictions will always have an uncertainty aspect due to the non-linearity of the atmosphere. Hence, several predictions with varying initial settings are produced and used to determine the level of certainty in the central prediction (Golding 2018.)

Murphy (1993: 283-287) has identified three qualifications for good weather forecasts. The first feature is *consistency* which refers to the connection between the forecaster's judgement on the data where the forecast is derived from and the final forecasts. Forecasts are based on a large amount of data and mainly on the computer modelling, a person's understanding is needed to compile the final forecast. Consistent forecasts are made based on the forecaster's best judgement on the data. The second qualification is *quality* which is the correspondence between forecasts and the observations made based on them. It includes several aspects such as accuracy (comparability between a forecast and the actual weather), reliability (level of bias in the forecast), resolution (acknowledging spatial and temporal differences) and uncertainty (acknowledging variance of the observations). The third qualification is *value* which refers to the value of the forecasts for the users, whether they are individuals or institutions, in choosing the right actions. The value approach can be divided into ex-post and ex-ante approaches. The former refers to the value of the forecast after the forecast is received by the user and when the user is expected to utilize the information in the forecast in decision making. The latter, ex-ante approach, refers to the estimated value of the forecast before it is available for the user.

Patt & Gwata (2002) have identified six constraints to forecasts effectiveness. Credibility may arise if past forecasts have not been accurate and especially is forecasts are communicated deterministically and not probabilistically. Also, the reputation of the messenger may cause low credibility. Legitimacy constraints may arise if users question the political agenda of the communicator. This can take place if farmers do not understand the development of the forecasts and if they are not in line with traditional forecasts. Scale can be a challenge when the forecasts cover large areas and are not downscaled enough. If users of the forecasts do not understand it, it becomes possible that they use it incorrectly or not at all. This is called the cognitive constraint. Procedural constraints may take place is standard operating procedures prevent using new information. Lastly, if the forecasts do not contain enough new information it is possible that farmers make a choice of not using it.

Weiss et al. (2000) recognize the difference between weather data and information. Data are digits with appropriate units for example degree Celcius or mm of rain and they come from observation or predictions. According to Weiss et al. these are not useful for making decisions as themselves. Information in the results of utilizing statistical simulation or other types of models and can be used for decision making. Agrometeorological information cannot be standardized since the end-users of the information are a very diverse group from farmers to institutions and governments.

3.1.1 Traditional knowledge on weather and climate

According to a study on the use of WCIS in Malawi, farmers rely on indigenous knowledge and personal evidence over scientific WCIS in their agricultural decision making. This was due to the low reliability and relevance of the information they had access to. The information was rather unreliable and not local specific (Coulibaly et al. 2015.)

Traditional knowledge (TK), also terms of local, indigenous, folk knowledge and vernacular are used in the literature, generally means knowledge that is place-based, roots from the culture and is often affiliated to communities that have strong connection to the environment. This kind of knowledge is usually a result of experiences and observations and is passed on through oral communication as more informally compared to scientific knowledge. It is usually seen as a counterpart to scientific knowledge but according to Orlove et al. (2014) just as a representation of traditions but more as a versatile and diverse empirical system that is able to learn from other systems. A lot of research has been made on indigenous knowledge in agriculture, biodiversity, and forest but not as much on climate. Research interests are guided by intellectual property interests and organizational levels. Climate knowledge does not have value in terms of patents and climate organizations usually operate on national and higher levels while projects and programmes dealing with indigenous knowledge operate on grassroot level. Nevertheless, some aspects of indigenous climate knowledge are indicators in weather forecasts and seasonal variability, connection to agricultural practices and the use of indigenous knowledge in scientific work. (Orlove et al. 2010: 244.)

Indigenous and local traditional knowledge plays a role in many areas. Traditional ecological knowledge is part of the local culture and the environment and it is knowledge, practices, and beliefs about the relationships within living beings and the environment that cumulatively move within a community from generation to generation. Traditional knowledge has been more and more acknowledged and accepted by the scientific community and both differences and similarities have been identified between traditional knowledge and so-called western science. Narratives related to climate change can be found in every continent and traditional and indigenous knowledge has resulted in adaptation actions to mitigate the impact of climate change. Such knowledge can be used as complementary information in regions where scientific data is limited. Generally, indigenous knowledge can be a valuable tool for climate change research as well as adaptation and mitigation processes (Aleksander et al. 2011.) According to Nyong et al. (2006) indigenous knowledge systems have been used in climate change mitigation measures in the Sahel area in terms of emission reduction and carbon sequestration and substitution. For adaptation purposes, indigenous knowledge has been used in weather forecasting, vulnerability assessment and in the execution of adaptation measures.

Traditional knowledge has been used by farmers and pastoralists in Africa in different ways. Signs in nature and in the environment have been used to indicate especially the onset of rainfall and the amount of rainfall. Radeny et al. (2019) have categorized indicators into three groups:

meteorological, astrological and biological indicators. Meteorological indicators are, for example, the appearance of certain types of clouds, changes in wind strength and direction, thunder without rain or high night temperatures. Also, cessation of rainfall has been forecasted through TK, by noticing clear sky, more frequent drizzles and low morning and evening temperatures, for instance. Biological indicators refer to changes in behaviour of animals or changes in plant activity. Such indicators can be, for example, appearance and behaviour, of certain birds such as swallows flying and coucals singing which are considered as signs of short rain season. Also, the appearance of certain insects such as ants in large numbers and behaviour both domestic and wild animals are seen as indicators of upcoming rainfall. Changes in the behaviour of animals are believed to be driven by increased air pressure and aroma from volatile compounds that increase when humidity changes. Other biological indicators are flowering or shedding of certain plants. This is believed to be results from changes in humidity and other atmospheric conditions. The third group, astrological indicators, are for example specific star alignments or appearance of the moon (Radeny 2019; Galacgac & Balisacan 2009.)

In this research term traditional knowledge is used to describe the knowledge that is used to predict the weather based on a person's own senses and observations in the research area, is based on generations experience and is mainly learned through informal interactions.

3.1.2 Role of weather and climate information services in agriculture

Weather and climate information services are meaningful factors in agricultural productivity in terms of managing risks regarding weather and climate variability and change. Therefore, WCIS plays an essential role also in achieving the Sustainable Development Goals (see more for chapter 2.1). Understanding the connection between agricultural production and WCIS has been more acknowledged, hence, WCIS has been more available also in Africa which is characterized by low agricultural productivity, lack of investments and vulnerability to weather and climate related risks. The majority of the African countries are now able to provide monthly and seasonal forecasts, agrometeorological forecasts and extreme weather alerts. Different user groups in Africa use different kinds of information for different kinds of purposes. Farmers most likely utilize daily and seasonal forecasts as well as drought and rainfall onset predictions. The information is used in choosing the right field and crop, in timing the activities, in conservation of water and in stocking. Pastoralists utilize sub-seasonal, flood and rainfall onset forecasts, and extreme event warnings. Such information is used in stocking, moving livestock, selling firewood and using veterinary services. Lastly, organizations which mainly use seasonal climate forecasts for food security planning (Vaughan et al. 2017: 2-3, 7-8.)

Especially in the African continent, farmers rely on rain-fed production and many areas suffer from lack of weather information systems which could help farmers to plan crop seasons and to adopt better farming practices. Weather and climate information might not be available at all or it is inadequate or those who would need it the most do not have access to it. Without adequate weather information farmers, for example in Somalia who experience severe drought and poor rainy season, do not have knowledge of how long and how intense the droughts will be. In Ivory Coast, cocoa farmers experience heavy downpour which can lead to flooding. Without weather data, they are not able to mitigate risks (Yeboah 2017.)

According to Roudier et al. (2014), climate forecasts have potential in improving the resilience of African agriculture to climate shocks. The study covers farmers from two agroecological zones in Senegal. Introduction of seasonal and decadal forecasts affected farmer's practices in most of the cases. The most common change in practices was choosing better sowing date and crop variety. Farmers in Nigeria have benefitted especially from 10-day and seasonal forecasts of which the former alone is more beneficial than the latter alone. Additionally, farmers with several adaptation strategies available have benefited more from forecasts (Roudier et al 2016.) According to a study by Vaughan et al (2017: 9), users of WCIS have benefitted from the information obtained in terms of increased yields, decreased yield losses and growth in household income through increased yield and stocking of livestock.

There are indications that users who have access to several types of information receive better yield. Regarding seasonal forecasts, the benefit takes at least a year to actualize which implicates that it takes some time for the user to adapt the information. Also, those farmers who have received training in the use of WCIS and those who are in connection with local authorities in terms of WCIS issues had relatively higher household income (Vaughan 2017: 8-9.)

3.2 Theorizing weather and climate information access and communication

This section creates an outlook of applied theories for structuring weather and climate information services. While weather is rather easy to understand as a concept since it is something that can be personally experienced every day and used for decision making, climate is relatively more difficult to understand due to its abstract nature. Therefore, it can be expected that information on weather and climate require different communication processes (Hansen et al. 2019: 6.)

3.2.1 Access to information

When considering the use of WCIS, for the user accessing the information is the first step. Ribot & Peluso (2003) have discussed the definition of access. They state that access is the "*ability to benefit from things*" and they want to differentiate it from what they call the classic definition for property "*the right to benefit from things".* They claim that access is more about power than rights. Regardless of that, Ribot & Peluso use the term *right* when discussing the different access categories. They define rights-based access as access that includes the factor of law, custom or convention and it includes two separate sub-categories legal and illegal access of which the former is enforced and accepted by law and the latter is when the benefit comes through illegal action. Those who do not have property rights must somehow gain access for example through payment or services. Rights that are enforced by the law, custom or convention define who controls and maintains the access. Illegal access is gained through force and is against legal and social approval (Ribot & Peluso 2003: 153.) It is not expected that WCIS would include rights-based access as whether a person has a right to access information or services but gaining access might require, for example, a payment.

The concept of access includes also different kinds of structural and relational mechanisms that either enable or prevent access. Access to technology can, for example, comprise electricity which can be used for using a certain ICT-device. Access to capital defines who has and who does not access the resources such as information and services for example through fees or payments. Access to markets, access to labor and labor opportunities, access to knowledge, access to authority all shapes who can benefit and how from resources. Regarding WCIS, those who have access to knowledge, have a possibility to benefit from resources, natural resources in this case, more efficiently. Access to a resource can be obtained also through social relations such as through a social identity or a membership in community or group. Lastly, access can be obtained through negotiations of other social relations such as friendship or trust (Ribot & Peluso 2003: 162-172.) Information on weather and climate change is expected to disseminate through social networks and through social interaction and in those cases friendships and membership in certain group play an important role.

According to Vaughan et al (2017: 6-8), access to WCIS in Africa varies across regions and between different livelihoods, demographics, and types of information. There is evidence that in East Africa and Southern Africa WCIS is more available than in Central and West Africa. Additionally, farmers seem to have better access to WCIS than pastoralists which corresponds with the different types of utilization of these groups (see more for chapter 3.1.2). Thirdly, there is an indication that (daily, monthly, etc.) weather information is better available than seasonal predictions. Lastly, men seem to have better access to WCIS than women and the use of information sources and channels differs between men and women (Manfre & Nordehn 2013.)

3.2.2 Models of communication process

When transferring information to the users the process of how it is done greatly influences the user's ability or will to utilize the information. Shannon's model of the communication process was the first general tool for modelling communication processes and was suitable for various disciplines. The model consists of basic constituents that clarify how communication functions and therefore also explains the challenges. The components of the models are 1) information source which is the creator of the message, 2) the message which is sent by the source and received by the destination, 3) the transmitter which is either a technological devise such as a phone or in personal interactions a mouth which creates a sound and a body that creates and gesture, 4) the signal which flows through a channel and in personal interactions sounds and gestures include various signal systems that differ between channels and modes of transmission. Signals can also be radio waves, text and pictures, 5) the carrier or channel that can be air, electricity, radio waves or for example paper, 6) noise which is a signal that disturbs the initial signal. This is mainly connected to technical devices and nowadays rather insignificant due technological development, 7) the receiver which can be for example eyes or ears or technical device such as telephone or TV 8) the destination which is the person who receives, consumes and processes the message (Duckham et al. 2003: 33-34; Foulger 2004.) Regarding WCIS, the components of the communication process can consist of ICT-devices, face to face communication, sound, pictures etc., these more in detail in the following sections. Foulger (2004) emphasizes that this model among most of the communication models is extremely simplified and the reality is much more complex. Most of the sources are also destinations and vice versa. All the components can be layered serially and in parallel in a way that compiles a variety of transmitted and received signals. Foulger also states that the model is more of a model of the flow of information rather than a model of communication.

When new weather and climate information is accessed and adopted by the end-user, it is beneficial that the information is disseminated to other end-users. This also creates a new source of information when a farmer can receive information also from other farmers. Rogers' (1995) theory on diffusion of innovation describes the process of how innovation is communicated within a society or a community using specific channels and in the context of time. The message communicated, an innovation such as a new farming practice or a new crop type, always includes a new idea. In the context of this research, information on weather and climate change. According to Rogers, communication is *"a process in which participants create and share information with one another in order to reach a mutual understanding"* as individuals exchange information in a two-way process. Diffusion also creates a social change when an innovation is invented, diffused and adopted or rejected leading to a change in society. Rogers points out that some authors make a difference between "diffusion" and "dissemination" where the first refers to spontaneous and unplanned spread of innovation whereas the latter refers to diffusion that is in one way or another directed or managed. In his texts, however, Rogers only uses the term diffusion when referring to any of them and does not make a difference between them (Rogers 1995: 5-7.)

Diffusion of innovation consists of four essential elements: innovation, channels of communication, time and social system. These are the key variables when studying diffusion. Innovation can be an idea, an object or a practice that is new for an individual or for another adoption unit. In this context, innovation does not need to be completely new but, instead, new in terms of knowledge, persuasion or just a decision to adopt. Three important points of interests of the innovation are the difference between the first adopters from the last adopters; the effect of the attributes of the innovation to the adoption; and the point in the diffusion curve when it rises radically when interpersonal networks become activated and a significant number of adopters are using the innovation (Rogers 1995: 10-12.) The rate of adoption can be observed through the characteristics of the innovation. Relative advantage refers to the degree to which an innovation is seen better as the idea it replaces; compatibility is the degree of with the innovation is considered being in line with the existing values, past experiences, and needs of adopters; complexity is the degree of which the innovation is seen difficult or easy to use; trialability is the degree of which the innovation can or cannot be tried before full adoption; and observability refers to the degree of which the results of the innovation are visible for other potential adopters (Rogers 1995: 15-16.)

Communication channel is the route a message is transferred from a person to another. The nature of the relationship between these two actors determines the environment for the message to be transferred from the source to the receiver. Channels of communication can be for example mass media channels which are good in reaching a great number of people whereas interpersonal channels, as face to face communication, can be more effective in terms of accepting a new idea on an individual level (Rogers 1995: 18.) Effective communication is more likely to succeed between individuals who are similar in certain attributes, for example, beliefs or education or they share the same social group, live in the same area or work in the same place (Rogers 1995: 18-19.)

Time plays a role in the diffusion of innovation theory in the innovation-decision process, the innovativeness of an individual and in the rate of adoption. The innovation-decision process includes five phases: knowledge as when being aware of the existence of the innovation, persuasion as when an option about the innovation is made by an individual, decision as when an engagement in activities leading to innovation related choices, implementation when the innovation put into use and confirmation as when reinforcement for the innovation decision is searched (Rogers 1995: 20.) Innovativeness varies between different adopter groups. Innovators as being the first adopters followed by early adopters, early majority, late majority and finally laggards. Rate of adoption reflects these groups as well and is the relative speed of the innovation that is being adopted and it forms a cumulative frequency curve (Rogers 1995: 22-23.)

The social system where innovation is being adopted plays another significant role in the diffusion process. The system of which the diffusion takes place consists of individuals and/or different kinds of groups. Different social systems have their own structures framed, for example, with a bureaucratic organization with different individual positions influence the social structures. Different social systems also have distinctive norms that guide the behaviour of individuals (Rogers 1995: 23-24, 26). Rogers has also identified different innovation-decisions which are determined by internal or external influence. Optional innovation-decisions are made by an individual without external influence, for example, other individuals in the same social system. However, it has to be taken into account that social norms and networks will have an effect. Collective innovative-decisions are made by individuals in the social system through consensus. Authority innovation-decisions are made by individuals in the social system who have gained a power status. Lower status individuals in the system do not have influence in the matter in question (Rogers 1995: 28-29.)

Rogers' theory has faced criticism due to its versatile application but, yet, with weak cohesion between different studies and hence it suffers from lack of stagnancy and consistency. Lack of emphasis on cultural differences and norms and to the fact that societies and networks are such complex systems also have an effect on research and research results. Consequently, the diffusion of innovation theory is adaptable but when conducting a study and applying the theory these factors need to be taken into account. Rogers himself has also acknowledged a few points of criticism in his theory. A pro-innovation bias refers to the implication that the innovation should be adopted by everybody in the society and to the assumption that adopting the innovation always bring something positive. Individual-blame bias refer to the assumption that the individual is alone fully responsible for adopting or non-adopting the innovation and that the origin of the innovation does not have any role. There is also an issue of equality and whether the negative outcomes of the innovation are considered and how different socio-economic roles affect the adoption (Rogers 1995: 100-129.) Goss (1979), have studied the application of the diffusion theory among farmers in developing countries and made observations on the negative impacts. For example, there was evidence on the growing equality gap in spite of the assumption that innovations spread homogenously. Goss also observed that the farmers most in need benefited relatively less than others from innovation in development projects. Lastly, those farmers who did not adopt the innovation were impacted by the process when adopters' increased production, for instance, affected the general price level and economic environment.

It is worthwhile to note that the factors behind these criticisms may potentially affect any adoption of new information or practices regarding WCIS. Also, users of WCIS are part of certain cultural and social structures that have their specific norms which may have an influence on the behaviour towards new information and communication with other individuals. Available practices are not necessarily in line with local customs and, also, local language and manners are something worth acknowledging. Different social structures may also have different ways and different structures to communication (varying neighbour relationships, community leadership structures, etc.), hence, weather and climate information is disseminated differently in terms of routes, volume, and quantity. Individuals (with different socio-economic roles) may also have different abilities to come across with new weather and climate information and practices (as the individual-blame bias).

Hansen et al. (2019) have studied structured participatory communication processes for supporting farmer's understanding of climate change and the ability to utilize the information as well as for increasing the willingness to act. Participatory communication processes can function as a counterpart for traditional formal learning and learning through social networks. They also help in solving challenges related to the uncertainty of the information and to overcome cognitive challenges in learning. Analytical processing is used when the information is received through statistical description and experimental processing when the information is received through repeated experiments, hence, the learner uses a different type of thinking process depending on how the information is received. Since experimental processing is connected to learners' own experience and emotion, it often overtakes analytical processing.

In disseminating climate information both the format and communication channels play an important role. Media formats such as videos and radios are good and efficient ways to reach people in local languages. Over three-quarters of the world's population uses mobile networks and mobile phones that are good tools in quick climate communication. Another communication devices are satellites which use short messages to send information and warnings to remote communities. Along with long term projections and modelling, information about imminent extreme events is essential for communities. Early warning systems require climate information for risk assessment, hazard monitoring, communication and response measures (WRI et al. 2011: 58-60.)

Climate Change and Resilience Information Center of CARE has studied climate change communication in Kenya. Firstly, also they pay attention to the nature of communication and state pointing out that there is a difference between information dissemination and communication and that for improved knowledge on climate change information should be communicated rather than just disseminated. They see communication as a two-way process where the receiver of the information has an active role. Secondly, they have identified a communication channel that transmits the information to the end-users. The first group of the chain includes country, for example, government officials, traditional forecasts, NGOs, media, private sector, and technical departments. The second group, intermediaries, includes extension officers, chiefs, religious leaders and media. And the third group, end-users are farmers, agro-pastoralists and community members. Communication tools identified are written material such as brochures and posters; media, field visits to schools for instance; meetings and gatherings held by community leaders including religious meetings and other group meetings; face to face communication in informal meetings and other social gatherings; and information and communication technology as text messages, web sites and social media (Gbetibuo et al. 2017: 55-56.)

Regarding WCIS in Africa, agricultural extension services under governments, development NGOs and related enterprises hold an essential role. They create advisories on weather, climate, and agriculture, and communicate the information to the communities. In addition to traditional learning and participatory methods as events implemented by the institutions, the so-called training of trainers is an approach used especially by NGOs where information is distributed to the communities through trained trainers who are members of the community. There is evidence that through this approach significantly larger amount of people can be reached. Moreover, farmers significantly rely on their social networks, such as other farmers in the area, family, relatives and other acquaintances related to agriculture in terms of receiving and sharing information. (Hansen et al. 2019; Vaughan et al. 2017; Manfre & Nordehn 2013.)

While so-called human-based sources of information, such as social networks and different educational events, there are different types of information and communication technologies, ICT for the purpose of information dissemination. According to several studies, it is evident that radio is a very common and preferred source of weather and climate information for farmers across Africa. Radio is easily accessible, and the information is seen as valuable. Other sources and channels of information are e.g television, internet and mobile phone application and games. There is evidence that when both human and technology-based communication channels are available and used, it is more likely that the received information is used in practice. Also, it seems to be the most popular communication channel. ICT is good in reaching a large number of people in remote locations with low cost and with real-time information that can be in a form of audio, visual or written. Hence, farmers with different levels of education and for example literacy are able to utilize the information. (e.g. Clarkson et al. 2018; Manfre & Nordehn 2013.)

Manfre & Nordehn (2013) have studied differences between men and women in using technology-based information channels. As was mentioned previously, men have somewhat better access to information compared to women. There is also a difference in sources of information as women's information channels are situated closer to their homes while men are more available to move around and can socialize further away from home.

4 Local context of the Taita Hills

This chapter presents climate change and weather information services in the local context of the Taita Hills in Kenya and also explains geography of Kenya, the Taita Hills and Wundanyi Sub-County which is the specific location of this research.

4.1 Geography of Kenya and the Taita Hills

Kenya is located in East Africa neighboured by Somalia, Ethiopia, South Sudan, Uganda, Ruanda, Burundi and Tanzania, and with a coastline by the Indian Ocean. The current climate is generally tropical but varies along with the topography from the coastal plains in the eastern part of the country to the western part of the country, the eastern edge of East African Plateau and the Great Rift Valley. Central and western highlands cover approximately 18 percent of the land area and are agriculturally high or medium productive areas. Almost half of the counties in Kenya are on arid or semi-arid land (ASAL). Arid land is mostly pastoral while semi-arid lands are agro-pastoral with crop or livestock production systems. Temperature varies from the 29 ºC in the coastal regions to 15 ºC in the high-altitude regions. Annual variability is low, two degrees in the coolest seasons.

Rainfall in Kenya is bi-modal characterized by low-pressure cells and heavy precipitation originating from the adjacent of the Equator called Inter-Tropical Convergence Zone (ITCZ). The location of it changes throughout the year when it migrates south crossing Kenya in October to December creating so-called short rains and back north in March to May creating so-called long rains. These two rainy seasons are the distinct wet seasons in the country. The average rainfall per month during the rainy seasons is approximately 50-200 mm but can be up to 300 mm, thus having great variability. Migration of the ITCZ is affected by surface temperature in the Indian Ocean and the most well-known effect is the El Niño Southern Oscillation (ENSO) which causes higher rainfall during the short rain season. The other phenomena La Nina as an effect of colder surface temperature creates drier periods (McSweeney et al. 2012: 1; Njoka et al 2016; GoK 2018.)

Kenya has experienced economic growth as well as human development, such as in education, during the past years. In 2016, it became a member of the lower middle-income countries with its gross national income (GNI) per capita US $1.380. Agriculture plays an essential role in the economy of Kenya. It contributes 29 percent directly and 27 percent indirectly to the GDP. 18 percent of the formal employment and 80 percent of the informal employment is in the field of agriculture. The population of Kenya in 2019 is nearly 53 million and in 2016 close to 36 percent was living under the poverty line (MoALF 2016: 3; Worldometers 2019; World Bank 2018; KNBS 2018.)

This case study was carried out in Wundanyi Sub-County in Taita-Taveta County in South-Eastern Kenya. Taita Hills (03º25'S, 38º20 E) cover approximately 1000 km2 hilly area by the Tsavo plains. The biggest residential areas are the city of Voi with a population of nearly 90 000 and Wundanyi town which is the administrative capital of the area. The total population in the county in 2018 was nearly 348 000, 50.2 percent male and 49.8 percent female. The estimated total population in 2018 in Wundanyi Sub-County was nearly 68 500 persons. Topography varies from 600 m above the sea level to Vuria peak with an elevation of 2 208 m above the sea level. Taita Hills experience two rainy seasons in March-May/June and October-December with high annual variability in precipitation. Land use in Taita Hills is mostly intensive agriculture and grazing, especially in the foothills and plains. Expansion of agricultural practices has led to a significant loss of forests due to firewood, charcoal, and agricultural production and it is estimated that half of the cloud forests were turned into agricultural land between 1955 and 2004. Largest of the still remaining forest areas are situated in remote locations (County Government of Taita Taveta 2018: 3-6, 12-13; MoALF 2016: 4, 11; Pellikka et al. 2009; Figure 2.)

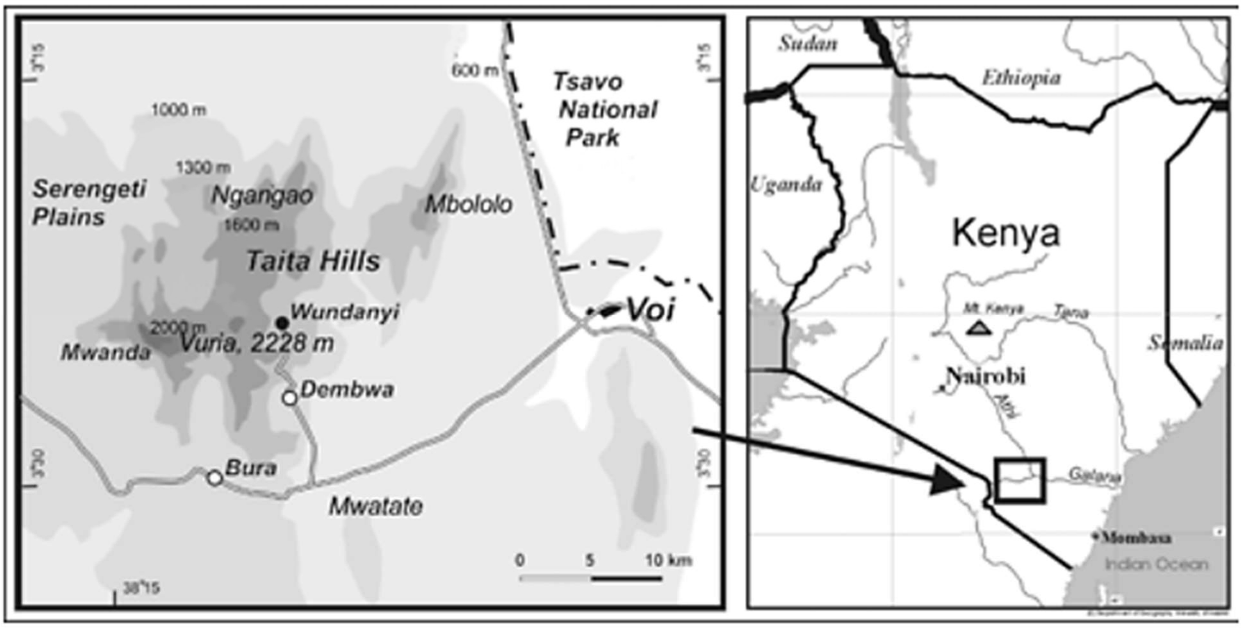

Figure 1 Map of Taita Hills (Pellikka et al. 2004.)

There are four ethnic groups in Taita-Taveta County, namely Wataita in Taita Hills, Wataveta in Taveta, Wasagalla in Sagalla Hills and Wakasigau in Kasigau Hills of which Wataita make up the majority by approximately 80 percent. The latter two groups are, however, often regarded as part of Wataita due to the similarities in their language and location. In Taita Hills, the local language Kitaita has two main dialects and several micro-dialects. Kiswahili is also spoken in the area as well as English. In addition, other ethnic groups in the county are Kambas, Maasai, Luos, Kikuyu and Somalis (Mkangi 1983: 21; County Government of Taita Taveta 2018: 3).

Climate in Taita-Taveta county is strongly characterized by South- Eastern winds. The area is mainly relatively dry but Taita Hills experience condensation of moisture and hence receive more rainfall during the rainy seasons, i.e. highlands receive more rain compared to the lowlands. Arable land covers 12 percent (205 500 ha) of the total land area in the county (County Government of Taita Taveta 2018: 6; MoALF 2016: 7.) According to Jaetzold et al. (2010), Taita-Taveta county is divided into eight agro-ecological zones based on altitude and mean annual rainfall (Table 1). Boitt et al (2014) have defined ten agro-ecological zones using the topography and characteristics of rainfall and typical crops (Table 2).

Table 1 Agro-ecological zones in Taita-Taveta county (Jaetzhold et al. 2010.)

Zone	Altitude	Mean annual rainfall	Location
L5 Lowland zone	below 610 m	bimodal rainfall	Tsavo National Park and Voi
L6 Lowland zone	610 – 790 m	480 – 680 mm	Mwatate, Taveta and Voi
LM6 Low midland zone	below 790 m	bimodal rainfall	Tsavo National Park, Mwatate and Voi
LM5 Low midland zone	790 – 980 m	480 – 700 mm	Wundanyi, Mwatate, Taveta and Voi
LM4 Low midland zone	910 – 1220 m	600 – 800 mm	Wundanyi, Mwatate and Taveta
UM4 Upper midland zone	1220 – 1520 m	700 – 900 mm	Wundanyi
UM3 Upper midland zone	1370 – 1690 m	900 – 1200 mm	Wundanyi
LH2 Low highland zone	above 1200 m	more than 1200 mm	Wundanyi

Table 2. Agro-ecological zones in the Taita Hills (Boitt et al. 2014.)

Zone	**Descriptor**	**Characteristics**
Z1 - Z2	Lowlands	- Higher temperatures, low rainfall. -Crops: Typically sisal.
Z3 - Z4	Upper Lowlands	-High temperatures and low rainfall. - Crops: Sorghum, millet, mangoes, early maturing maize and beans.
Z5-Z6	Lower Mid-lands	- Mid temperatures, average rainfall - Crops: Mangoes, maize, cassava, sweet potatoes.
Z7-Z8	Upper Mid-lands	-Low temperatures, above average rainfall. -Crops: Bananas, avocadoes, maize, sugarcane, potatoes, tomatoes, agro-forestry.
Z9-Z10	Highlands	Lower temperatures, higher rainfall. Crops: Agro-forestry, Indigenous trees (forests).

In Taita-Taveta, farming is the main livelihood and the main source of food. The agricultural sector in the county includes both commercial and subsistence farms and 70-80 percent of the workforce are involved in the agricultural sector. 95 percent of the households are practicing agriculture as a source of income and majority depend on a single income source mainly on crop and livestock related practices. The average farm size in the highlands is 0.4 Ha while in the midlands 1.5 Ha and 4.8 Ha in the lowlands. Small farm size contributes to low yield for many households. On a county level, 90 percent of the households grow maize, 46 percent beans and 31 percent cowpeas. More drought resistant crops are cultivated in the lower lands whereas also sisal production is common. In Taita Hills tomatoes and cabbages are the most common and important vegetables. The main livestock is chicken along with a dairy cow, sheep, goat, camel, and pig. Also, beekeeping and fish farming are practiced. Most of the farmers in Taita-Taveta county rely on rain-fed agriculture. Only 47 percent of the land with irrigation potential is irrigated. In Wundanyi Sub-County, only less than one percent of the land is irrigable and only 20 percent of this is irrigated. Such reliance on rainfall makes farmers exceptionally vulnerable to impacts of climate change, such as for unreliable rainfall patterns, lack of moisture during growing period, and heavy rains during harvesting. Increasing temperatures raise the risk of new types of pests and diseases. Farmers have limited access to proper seeds, fertilizers, irrigation and technology due to high poverty levels. Low access to assets easily leads to low productivity which endangers the overall livelihood (County Government of Taita Taveta 2018: 7, 25-27; MoALF 2016: 4-11.)

4.2 Impact of climate change in Kenya

According to the IPCC, it is evident that annual average land temperature will rise across Africa and it is likely that the temperature rise will exceed 2 °C. North Africa and southwestern parts of South Africa are likely to experience a reduction in annual average precipitation. Projections on changes in rainfall in sub-Saharan Africa are uncertain. Ecosystems in the African continent have already faced impacts of climate change, but the future impacts are likely to be significant. Additionally, already existing water stress will worsen and affect both ecosystems and humans, and climate change will also interact with other challenges and affect agricultural systems especially in semi-arid areas. Food production in Africa is one of the most vulnerable in the world due to its reliance on rain-fed crop production, high intra- and inter-seasonal climate variability, droughts, and floods. Together with poverty, this will make people extremely vulnerable to climate change (Niang et al. 2014: 1202, 1218.)

The effects of climate change in Kenya are evident. Generally, based on the observations from the 1960s, there is no statistically significant trend in rainfall, but rain patterns have become unpredictable, extreme weather events are more frequent and while some areas suffer from droughts, some areas experience severe floods during short rains. Changes in temperature vary between regions (Western; Northern & North Eastern; Central; South Eastern Districts; Coastal strip) and seasons (Dec-Jan-Feb; March-April-May; June-July-Aug; Sept-Oct-Nov). Since 1960, the mean annual temperature has increased 1,0 ºC and the frequency of hot days and hot nights has increased. It is expected that the mean annual temperature increases 0.8-1.5 ºC by 2030 and 1.6 ºC to 2.7 ºC by 2060. Temperature rise is higher in the northern parts of the country compared to other regions especially in periods from October to February. Additionally, a change in annual average minimum temperature, which has decreased in the northern part of the coastal strip, is higher than in the southern parts of the coast. Inland regions experience an increase in both annual minimum and maximum temperatures and the strong trend indicates general warming (GoK 2016: 5-6; McSweeney et al. 2012: 2.)

Most areas in Kenya are experiencing some decrease in rainfall which is mainly caused by the shortened time of the long rainy season from March to May. The short rainy season from October to December has indicated an early onset and late cessation of rainfall during the season from September to February. This may be caused by the more frequent occurrence of El Niño events together with relatively warmer sea surface temperature in the western Indian Ocean and relatively cooler sea surface temperature in the eastern Indian Ocean. Projections are indicating increases in mean annual rainfall and the increase in total rainfall is highest in October to December and proportional change is highest in January to February. There is also an indication that the increase in the proportion of annual rainfall is focused on heavy events (GoK 2016: 5-6; McSweeney et al. 2012: 3.)

According to the ND-GAIN (Notre Dame Global Adaptation Initiative) Country Index, which measures climate vulnerability to climate change and readiness to improve resilience, Kenya is in place 150 out of 181 countries. It is the 32nd most vulnerable to the impacts of climate change and the 40th least ready country in the world to adapt to the changes. Vulnerability considers exposure, sensitivity and adaptive capacity; readiness considers the economic environment, governance and social factors (ND-GAIN 2019.)

All sectors are expected to experience the impacts of climate change. Agricultural production is expected to decline especially in ASALs (arid and semi-arid land) as a result of increased temperatures and lower rainfall and overall crop yields in most areas are expected to decrease due to low precipitation and increased risk for pests, diseases, and weeds. Generally, this creates an increased risk for food security. Drought together with lack of pasture, lower access to water and high temperatures as well as a higher risk for diseases is likely to cause livestock deaths and hence a decline in production. Fisheries are expected to experience a decline in species and a higher risk of invasive species due to higher temperatures. Along with the agricultural sector, other sectors from environment, water and forestry to energy, health and transport have their respective impacts all affecting the development and wellbeing on a local and national level (GoK 2018.)

4.3 Weather and climate information services in Kenya

Kenya Meteorological Services (previously Kenya Meteorological Department) is the main provider of meteorological and climatological services for example to agriculture, water resource management, civil aviation and the private sector including industry, commerce, and public utilities. Other functions of the department are organization and administration of observations and the publication of climatological data; maintenance of efficient communication systems for rapid collection and dissemination of meteorological information for national and international use; coordination of research in meteorology and climatology; and evolvement of suitable meteorological training programmes (KMS 2015.)

Kenya Meteorological Department provides daily, weekly and monthly weather forecasts as well as seasonal forecasts. Additionally, it provides agrometeorological bulletins which include regional observations on rainfall and temperature, crop and weather review including phenological report, and expected weather and crop conditions as per region and weather station (KMS 2015.)

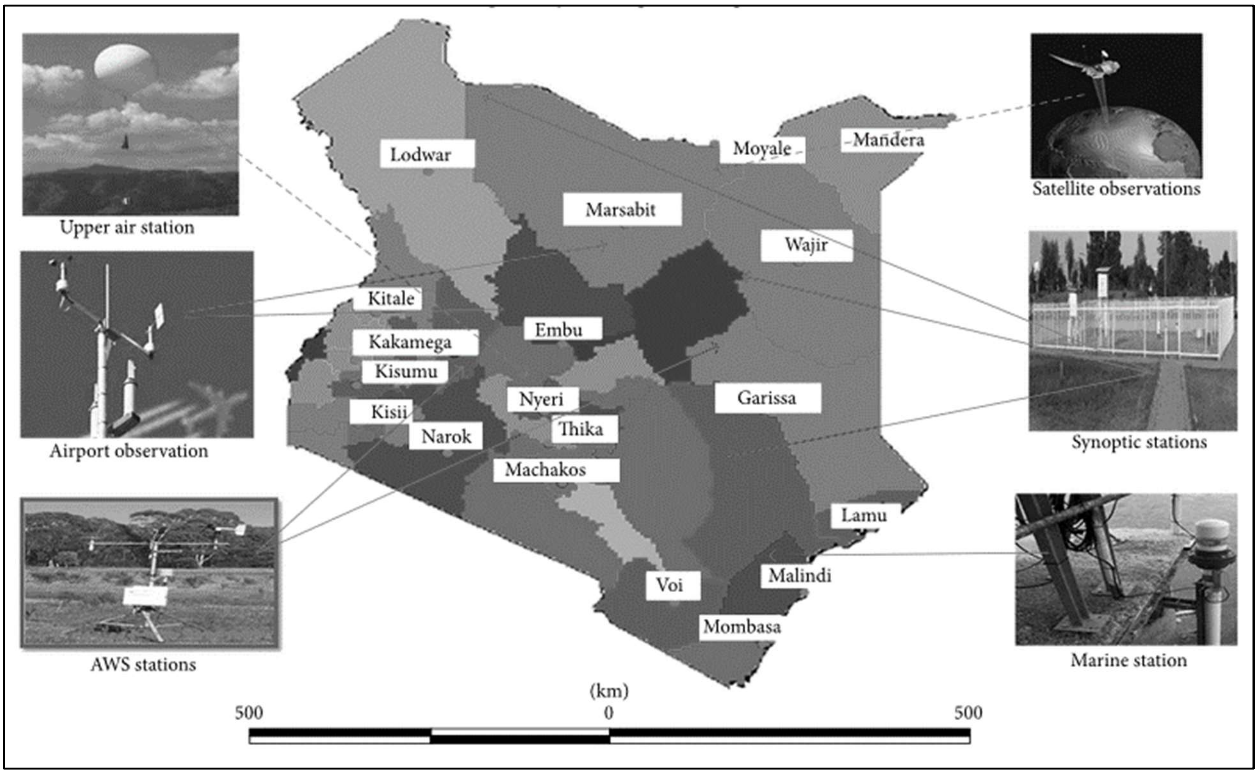

Figure 2 Meteorological observation stations in Kenya (Shilenje & Ogwang 2015: 4.)

Kenya Meteorological Services operates numerous meteorological and environmental stations around the country: 39 manned stations (shown in Figure 1.), over 1000 rainfall stations, 17 agrometeorological stations, 72 automatic weather stations, one upper air station, three automatic weather observing systems (for aviation), one global atmospheric watch station on Mt. Kenya, 2 urban environmental pollution monitoring stations and one ozonesonde station.

Dissemination of the produced meteorological information is organized through press releases, interaction with media personnel, radio and TV, email services, government line ministries, websites, and social media. Kenya Meteorological Services has decentralized its services into a county-level where offices of the county directors of meteorology, radio and internet projects, NGOs, sub-county development committee meetings and chiefs are used to disseminate weather information. Different regions require different weather information and despite the numerous observation stations some remote areas, especially in semi-arid and arid regions, suffer from inadequate observation network and poor spatial coverage (Shilenje & Ogwang 2015: 3-4.)

Agricultural extension services in Kenya are mostly decentralized and run by government, county, private and NGO based services. Extensions services used to be dominated by the government but there has to be a shift to a more diverse field of service providers. This has been expected to respond to the lack of human and financial resources. In 2012, there was one extension officer for 1000 farmers while the recommendation from FAO is one officer per 400 farmers. MoALF's guideline for minimum staff to farmer ration is 1:700 in the intensive mixed farming system, 1:640 in the agro-pastoral system and 1:1000 in the pastoral system. The government is also implementing a shift from top-down information delivery to more demand-driven services. This system requires more from the farmers when they need to actively demand information and be initiative in communicating and sharing. The extension services system aims to assist farmers to increase agricultural productivity, competitiveness, and sustainability, for example, by providing technical information and training, raising awareness on different opportunities and assisting with market linkages (GoK 2012: 7-8; MoALF 2017b: 5-6, 19.)

5 Research design

This chapter presents the outlines of the research design by first, outlining the methodology and presenting the research questions, secondly explaining the data collection process and lastly, creating an outlook of the data analysis process.

5.1 Research methodology and research questions

The research draws from empirical epistemology. Empiricism evolves from the research's aim to study access and use of weather and climate information services by people and their subjective experiences, thus the results will be verified by sense of experience or interview data as scientific instrumentation. The primary empirical data is in the focus of the research and functions as a starting point for the whole research process. Additionally, the research can be said to draw from constructivism and post-structuralism in terms of their nature to see that there are no readymade structures but, instead, knowledge is based on subjectivism and built based on the research process. Research targets are also seen producers of knowledge (Bryman 2016; Jupp 2006; Woodward et al. 2009: 29-30.)

Secondly, the research draws from a qualitative approach which means that it does not simply observe the numbers but rather goes behind the meanings and structures behind them. It is said that the qualitative approach is a way of understanding the empirical world. Qualitative research is interested in how people perceive things in their life and, as said, what kind of meanings they give to them. Qualitative research is also inductive as the assumption is that it creates new information and a new understanding of phenomena instead of verifying a hypothesis or a theory. As is geography as a discipline, qualitative methodology is a holistic approach since it is concerned with totalities and complete systems rather than isolated details. It looks at the research target in its context with its settings and networks and not as a framed individual and is interested in the way people think and behave in their environment (Taylor et al. 2016.)

Thirdly, the research is a case study focusing on a certain group with the aim of understanding the phenomenon in a particular context allowing a specific interpretation to be made. Often, and as in this research, the scope of the study is narrow and focuses on a limited number of target informants and on a specific geographical area. A case study observes a real-life phenomenon through elaborated contextual analysis of the components of the phenomenon and their relationships. The advantage of a case study is that it is conducted in the actual environment of the examined phenomenon and informants and hence brings the researcher closer to it. A case study also allows various research approaches, and both qualitative and quantitative methods to be used and to reveal information that is not available through experimental studies or survey research. Nevertheless, there are also some disadvantages regarding case studies. Such studies can easily lack thoroughness and results can be affected by the research process, thus lack in authenticity. Additionally, although case studies may aim for generalization of the findings, it has to be taken into account that the results are often based on a relatively small sample. Case studies are also said easily to be very labour intensive and produce a large amount of data that has to be acknowledged in the process (Yin 1984; Zainal 2007.). According to Yin (1984) there are three types of case studies: a) exploratory case study seeks for any points of interest which are potentially worthy of further studying; b) descriptive case study observes a certain phenomenon or phenomena within the data and aim to describe it as it is; lastly, c) explanatory case study aims to explain the phenomena within the data by answering why the phenomenon takes place. This research represents an explanatory case study since it aims, first, to observe access and use of weather and climate information services and secondly to explain causalities between the findings.

This research aims to create new information based on the experiences of the informants and the target is that such information can be utilized in a way or another. The target informants of this research are subsistence farmers in Wundanyi Sub-County in the Taita Hills. The objective is to find out whether they have access to weather and climate information services, type of accessed services (type of information and sources) and how the received information is used, if it is, and is it perceived beneficial in agricultural processes. In addition to weather and climate information services, the research acknowledges the role of traditional knowledge as a source of information. Additionally, the aim is to describe how the information is communicated to the informants and how they share it with each other.

Therefore, the research questions are:

- What kind of weather and climate information services (WCIS) are accessed by subsistence farmers in Wundanyi Sub-County in Taita Hills?
    - How such information is utilized and how it benefits the farmers?
- What kind of traditional weather and climate knowledge (TK) is accessed by the farmers?
    - How such information is utilized and how it benefits the farmers?
- How weather and climate information is communicated to the farmers and how they share information with each other?

WCIS in this research is considered being a combination of the data and the route from the origin to the end-users, however, this research focuses on the end-users and their experiences. Communication in WCIS can be divided into two sections, human-based and technology-based communication. These information sources, as defined in this research, are the actors that deliver the information to the end-users. Human-based information sources are Agricultural Extension

Officers, social networks and local administration. Technology-based information sources are technical devices such as mobile phones and TV Also, a newspaper is regarded in this group although it is not a technical device but still a source that does not include direct human interaction, such as face-to-face communication. This research will pay attention to the number and nature of information sources and consider factors, such as gender and age.

5.2 Data collection

The primary data is derived from the household interviews and expert interviews. It is seconded using the pre-combined theoretical framework including thematical literature and information on the local settings to support the findings from the interviews.

Sampling was done through semi-selective sampling to have a diverse group of the households in Wundanyi within one agroecological zone. Households were chosen based on their subsistence farming and the aim was to select households from various locations (both near and further away from main roads) and assumed income level (the building material of the house, e.g. mud and poles, and painted bricks). Chosen locations for household interviews in Wundanyi Sub-County were Wundanyi, Mgange, Werugha, Ngerenyi and Shungululu towns. The chosen respondents in the households were the persons who were present and willing to take part in the research. It was assumed that the interviewee represents also his/her household and not only him/herself. It is, however, important to note that the information possessed by the respondent does not necessarily represent the information possessed by all the other individuals living in the respective household. The ratio between men and women interviewees was 50/50. In some interviews, there was more than just the main interviewee present and this was regarded as a positive situation since it was assumed that the other members of the household were able to complement the information from the main interviewee. In addition to the household interviews, the sample group includes other users of WCIS and TK who are also part of the WCIS system, for example as information sources for the farmers. These are Agricultural Extension Officers, an NGO representative, representatives from Voi Meteorological Station and from Taita-Taveta University. In total, 35 interviews were made out of which 30 were household interviews and 5 expert interviews.

Executed interviews were semi-structured interviews. In semi-structured interviews, there is a list of questions and the research topic and these questions function as an interview guide. The interviewer follows the guide but gives space for additional topics that may arise during the process and the interviewee has an opportunity to express topics outside of the guide. There is a lot of flexibility, but the researcher has to follow the guide with every interviewee, i.e. same questions are asked from everybody, but every interview can bring new topics and aspects (Bryman 2016: 468-469.) The interview questions in this research covered the sources types and use of WCIS (making a difference between weather and climate information, and human and technology-based information sources), sources, types and use of TK, interviewee's potential observation on climate change and how interviewee communicate and share weather and climate information paying attention to forums, such as chiefs' barazas and farmer groups.

Spoken consent was taken prior to every interview. Consent is an agreement that the interviewee accepts the interview, the content of it and the use of it in the research. Basically, the aim is to secure research ethics. Although local people tend to possess rather good English skills, an interpreter was used in every household interview to give the interviewee an opportunity to use his/her own language with a perception that it makes it easier to express oneself. Some interviewees felt confident in using English during their interviews and in those cases the interpreter was not used unless something was unclear to the interviewer or to the interviewee and needed to be clarified by the interpreter. All interviews were recorded with a recorder, except one of which interviewee was hesitant to allow the use of the recorder. In that case, the interview was captured in a written form. The transcript, in this case, was not word for word but rather capturing the main points and thematic content of the interview. Prior to every interview, a short introduction of the research and the interviewer was made and, also, contact details of the interviewer were left if wanted by the interviewee. Additionally, the researcher applied and received a research permit from the local administrator. The research data was collected in the Taita Hills and Voi in Kenya in February in 2018.

5.3 Data analysis

The research data was analyzed using qualitative content analysis (QCA). As the qualitative methods in general, also content analysis is a flexible analysis method. The target is to quantify the research content through predetermined categories and codes, systematically and in a replicable way. Content analysis aims to describe characteristics of the data; to describe trends and patterns; to make inference about the causes and to make interference about the effect of content. This method was chosen since it analyses data by categories derived from the data, without restricting the informational content found in the data. Qualitative analysis was chosen since it is not expected that the respondent will bring out only comparable factors that could be analyzed just quantitatively. Additionally, the sample is relatively small to offer reliable quantitative information. Therefore, the analysis will emphasize the qualitative side of the data but will observe it also quantitatively and uses it as supportive information. (Bryman 2016: 258,303; Forman & Damschroder 2010: 40-41.)

The data was analyzed using Atlas.ti programme to identify the meaningful categories and codes in the transcription and to organize the data. Before the actual analysis, a transcription was made from the recorded data. The transcription process concentrated on the content in the data and did not include the nuances in the manner of speaking of the interviewee. QCA is based on codes and their meanings and connections. Part of the codes in this research were determined before the analysis during the compilation of the theoretical framework and the research design. Some codes were included during the close reading process and during coding. Pre-determined codes were set to focus on the sources and use of weather and climate information, differing weather and climate change; sources and use of traditional knowledge; and information sharing forums with the aim of achieving an understanding of the information network. The network was expected to include the information sources, both human and technology-based and the actors who receive and/or disseminate information.

6 Results

As was presented in the previous chapter, the results of this study are derived from the household and expert interviews, 30 and 5 interviews respectively. This chapter presents the main findings of the research according to the contextual framework. It presents the respondents' access to weather and climate information through ICT based sources, access to weather and climate information through human-based sources and lastly application of the information. ICT and human-based information sources differ when applying them to the Shannon's model of the communication process in terms of the components. For example, when receiving information from the radio, it is the device, sound and radio waves that are the transmitter, signal and carrier and when receiving information from a person, it is the person and for example sound and pictures that form the corresponding compounds. In this research, weather information is regarded as weather predictions, and climate information as well as climate change information as information on the causes, consequences and possible adaptation measures.

6.1 Farmer informant profile

From the household interviews, the gender ratio was half and half, compromising of 15 male and 15 female interviewees. Age distribution, seen in Figure 3, varied from the youngest of 19 years old to the oldest of 70 years old. In most of the age groups, women were relatively older than men, except in the youngest and oldest groups. All informants over 61 years were men.

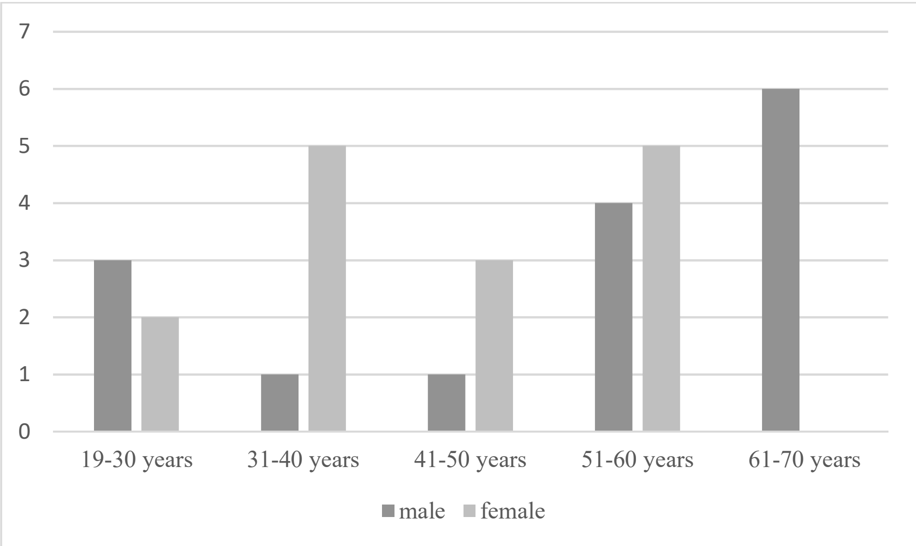

Figure 3 Age distribution of the 30 farmer informants

Education levels in this research were considered from the highest education level in the household. The assumption is that the information received is shared within the family and that the education benefits the whole household regardless of the bearer of it. The group with primary education were slightly bigger than with secondary education. Four informants stated they have a person with higher education in the household (Figure 4.) Although the education level was not necessarily the respondent's level of education, interviewed women reported more primary education than men.

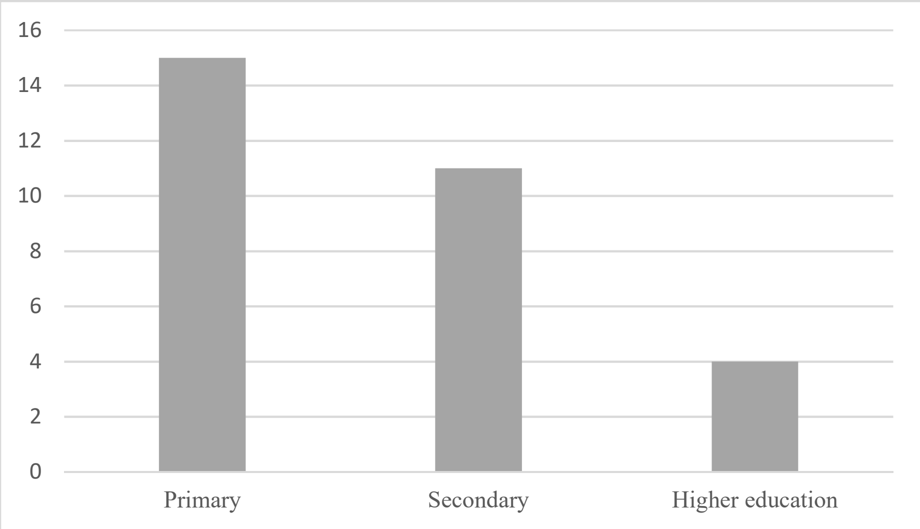

Figure 4 Highest education level in the 30 target households

Target households were relatively large in household members. The term *household* is used in this research instead of term *family* to emphasize those people who are staying in that specific household. Family would potentially consider family members staying elsewhere. The most common numbers of household members were four to seven members. Two households had eight members and one household ten members. Two households were only two-person households (Figure 5.) The assumption is that household with a larger number of families includes several generations and therefore potentially different technological skills and different social networks.

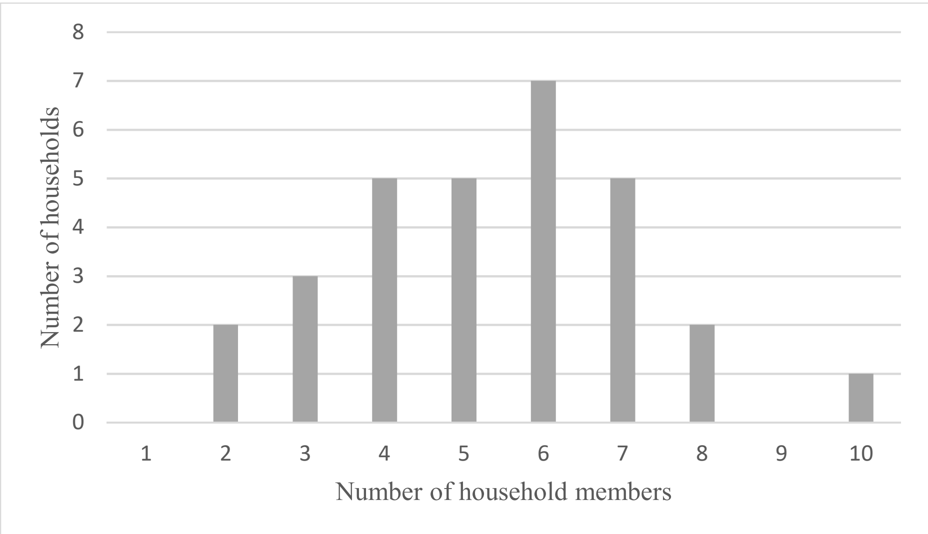

Figure 5 Number of the household members in the 30 target households

The size of the farm in the target households varied between 0.1 to 2.4 hectares, the majority of the farmers had less than 1 hectare. Agriculture was the primary source of income for all informants, four of them reported having one or two other sources as well such as small kiosk business.

The results are divided into three sections. First part presents the availability and access of ICT based information sources, second human-based information sources and third application of the information. Each section regards weather and climate change information separately. Local weather knowledge and social networks are considered in the second section.

According to the household interviews approximately half of the farmer respondents reported that they have not received any information on climate change (see more for sections 6.2.2 and 6.3.2), all respondents (30) noted that they have, however, noticed changes in climate in the research area within, at least, the last ten years. The most common observation was delayed rainy seasons and decreased rainfall (21 mentions) and increased temperature causing drought (16 mentions). One (1) mentioned heavy rain showers and one (1) changes in wind direction and strength (Table 3.)

Table 3 Observed changes in climate

	f (N=30)
Delayed rain season and decreased rainfall	21
Increased temperature	16
Heavy rain showers	1
Changes in wind direction and strength	1

As stated above, the most common observation regarding the weather was a decrease in rainfall. Both elderly and younger respondents had made the same observation that is it dryer and temperature is increasing which both has caused losses in crop production (Table 4.)

Table 4 Quotations on observed changes in climate

"I can say that the rainfall within the last ten years is declining. When I was young there was a lot of rainfall but now it is declining. It is drier. The temperatures are getting also really high, it is getting hotter." – Farmer, 39 years *"When we were growing up, we used to experience good yield but in previous years things have become more terrible. Farmers in this area have lost their maize. The rain has not been good although I'm getting something. Also, the temperature is getting higher, it is getting warmer."* – Farmer, 60 years

What comes to the effects of climate change, according to the expert interviews, the farmers have noticed the change mainly in the changes in rainfall. Years back there would be enough rain for maize to mature properly and there would even be too much rain for maize to dry. Also, in the mornings dew was a common sight. According to the experts, farmers generally have information also on the causes of the changes. Visual signs in the environment were a clear indication and it was stated that there used to be a lot of forests in Wundanyi area and the top of the hills used to be covered by trees. The loss of forest was said generally known to be one of the reasons for changes in microclimate. It was also noted that the change in people's attitudes and acceptance towards such information has changed. Years back people in the area were doubtful towards the idea that they can change their behaviour and thus make a difference in climate as well as in their own livelihood. After the first changes in agricultural practices, some farmers complained that they are doing more work, but nothing is changing. It was said that feedback from related trainings, however, indicates that general transition in behaviour is there.

6.2 Technology-based weather and climate information

ICT-based information sources are, for instance, radio, TV and smartphone which offer information straight to the user without human influence and interpreter. In this case, a newspaper was regarded as part of the ICT-group. Weather information was significantly more available and accessed by the respondents than climate change information. Results in detail below in two sections.

6.2.1 Access to weather information

According to the data, the majority (27) of the respondents have access to weather forecasts through ICT based information sources, i.e. they have at least one source of weather forecasts. Fourteen (14) respondents had one forecasts source, nine (9) respondents had two sources, three (3) respondents had three sources and one (1) respondent had four sources (Table 5.) Mentioned sources were radio, television, mobile phone and newspaper.

The most common equipment was radio with a frequency of 22 mentions and seventeen (17) respondents stated it was their primary sources of weather forecasts; the second common was television with a frequency of 17 and eight (8) stated it as a primary source; and third common was mobile phone with a frequency of 3 and two (2) mentioned it as a primary source. Newspaper was a forecast source with a frequency of 3 but no one stated it was their primary source. Respondents stated that radio and needed batteries are relatively affordable devices and generally common in the households. It was also stated that radio is easy to carry with can be taken outside while doing chores around the household. All respondents aged 50 and above, excluding two, stated using radio, while from respondents under 50, seven out of 13 stated using radio which indicates that radio is slightly more popular among elder farmers (Table 6; Table 7.)

From those (3) respondents who claimed not having access to any ICT information sources stated that the factor is economic challenges, or they are not generally interested in seeking such information.

Table 5 Number of ICT weather information sources accessed

	Farmers, N=30
No sources	3
1 source	14
2 sources	9
3 sources	3
4 sources	1

Table 6 ICT-based weather information sources

	f (N=27)
Radio	22
TV	17
Mobile phone	3
Newspaper	3

Table 7 Primary source of weather forecasts

	Farmers, N=27
Radio	17
TV	8
Mobile phone	2
Newspaper	0

The most common type of forecast was daily forecasts including information about precipitation, temperature, and wind as nineteen (19) respondents reported it as the primary type of forecast. Monthly forecasts were mentioned by four (4) respondents and seasonal forecasts by four (4) respondents as types of forecasts including information about precipitation especially, and also temperature and wind (Table 8.)

Table 8 Type of the weather forecasts

	Farmers, N=27
Daily forecasts	19
Weekly forecasts	0
Monthly forecasts	4
Seasonal forecasts	4

Respondents consistently stated that the most important aspect in weather predictions is rainfall, secondly temperature and wind. The timing of rainfall was stated being essential for successful agricultural production and hence for people's livelihoods.

According to the expert interviews, radio is an efficient way for farmers to receive weather forecasts. However, firstly, that depends on the access to radios although it was indicated that radios are rather affordable and, hence, accessible for many. Many radios are also easy to carry along while doing daily activities. Secondly, access to actual forecasts depends on the station that is listened to. Weather related issues may vary between stations and therefore the information received may differ although it was said commonly all of the stations have weather announcements. General income level was mentioned as a challenge to receive information on upcoming weather, for example, downloading information from the internet is potentially too expensive for low-income farmers. Information from the internet was also seen difficult to use due to a high amount of data which should be customized for them for easier understanding. Together with radio, mobile phones and TVs were seen as applicable devices to seek information on weather. Voi Weather Station would potentially broadcast radio programmes to reach the end-users of weather prediction but are financially limited and hence unable to do so. The radio and TV channels the respondents can access are national channels and provide mostly daily predictions which are generally not useful for agricultural practices.

Most of the respondents stated that they have access to daily forecasts that are highly unpredictable and hence not useful in agricultural purposes. Only four respondents were receiving seasonal forecasts which are for the purpose of agriculture since they foresee the short and long rain season. According to the expert interviews, farmers in Wundanyi rely more on the long rain season but that is more difficult to predict compared to the short season. Unreliability makes the forecasts less applicable for the farmers.

Alongside with the seasonal forecasts, all the other types of forecasts were regarded as unreliable and hence not applicable. Since Wundanyi is situated in the steep hills, predicting local specific forecasts is challenges in the first place but a second challenge is that there is no an operating weather station in Wundanyi that would produce data for KMS, therefore the Voi station, which gathers the measurements for forecast production, do not have the data exactly from the research area which makes the forecasts production even more difficult.

6.2.2 Access to climate change information

The majority of the respondents, nineteen (19) reported that they have not received information about climate change through any sources. Seven (7) stated that they have one ICT based climate change information source and 1 reported two sources. Seven (7) stated that they have heard something about in the radio, one (1) from TV and one (1) from the smartphone (Table 9; Table 10.)

Table 9 Number of ICT-based climate change information sources

	Farmers, N=27
0 sources	19
1 source	7
2 sources	1

Table 10 ICT-based climate change information sources

	f
Radio	7
TV	1
Smartphone	1

The information received was regular information about climate change and what kind of effects it has, i.e. causes and consequences. Such information from ICT based sources was not seen very relevant for the farmers since it did not seem to offer adaptation advice but offered more general information, such as a possibility of floods on a national level.

As was seen, ICT based climate change information sources were not very meaningful for the respondents and were not widely used compared to the weather information which was more available and accessed. Generally, the use of ICT was dominated by the daily weather forecasts.

6.3 Human-based weather and climate information

Human-based weather and climate information is received through respondents' social networks and social interactions. These networks can be for example neighbours as fellow farmers in the same area, church, relatives, farmer groups and chiefs' barazas. Also, information from agricultural extension officers is based on human interaction.

6.3.1 Human-based weather information

Respondents receive information on weather also from other sources than through ICT sources such as from radio. These sources are agricultural extension officers, community meetings and other people such as neighbours and relatives.

Neighbours were mentioned as a weather forecast source with a frequency of nineteen (19), secondly, agricultural extension officers were stated as a source with a frequency of fifteen (15). Barazas and other community meetings with a frequency of thirteen (13), farmer groups with five (5), a church with three (3) and finally relatives outside the housed with a frequency of three (3) (Table 11.) Part of these sources functions also as forums for sharing information more extensively about weather and climate. Information from other people including weather predictions was mostly information about upcoming rain.

Table 11 Human-based weather information sources

	f (N=27)
Neighbours	19
Agricultural extension officers	15
Community meetings /barazas	13
Farmer groups	5
Church	3
Relatives outside the household	3

Information received from the neighbours did not only include official weather predictions but also people's own observations on the weather, especially rain (see more for 6.3.1). Also, information from farmer group members, church and relatives was stated to be a mixture of information.

According to the expert interview, the agricultural extension officers receive rainfall predictions from the weather station in Voi and from them the information is distributed to some of the farmers. Some of the officers have social media groups where the information is shared. Overall the process of distributing the seasonal weather predictions starts from the original source, Nairobi Meteorological Department, to Voi Weather Station where the forecasts are localized for the Taita Taveta county. From there the predictions are distributed for the agricultural extension officers who distribute the information for the farmers within two weeks. They will develop an advisory that includes information on the expected rain volume, duration, and distribution. Then the officers will look at which crops will mature in that kind of rainfall looking at the characteristics of the rainfall. Another route for the information from Voi weather station is to the chiefs through the Commissioner's office, Deputy County Commissioner and the Assistant Commissioner (Figure 6.)

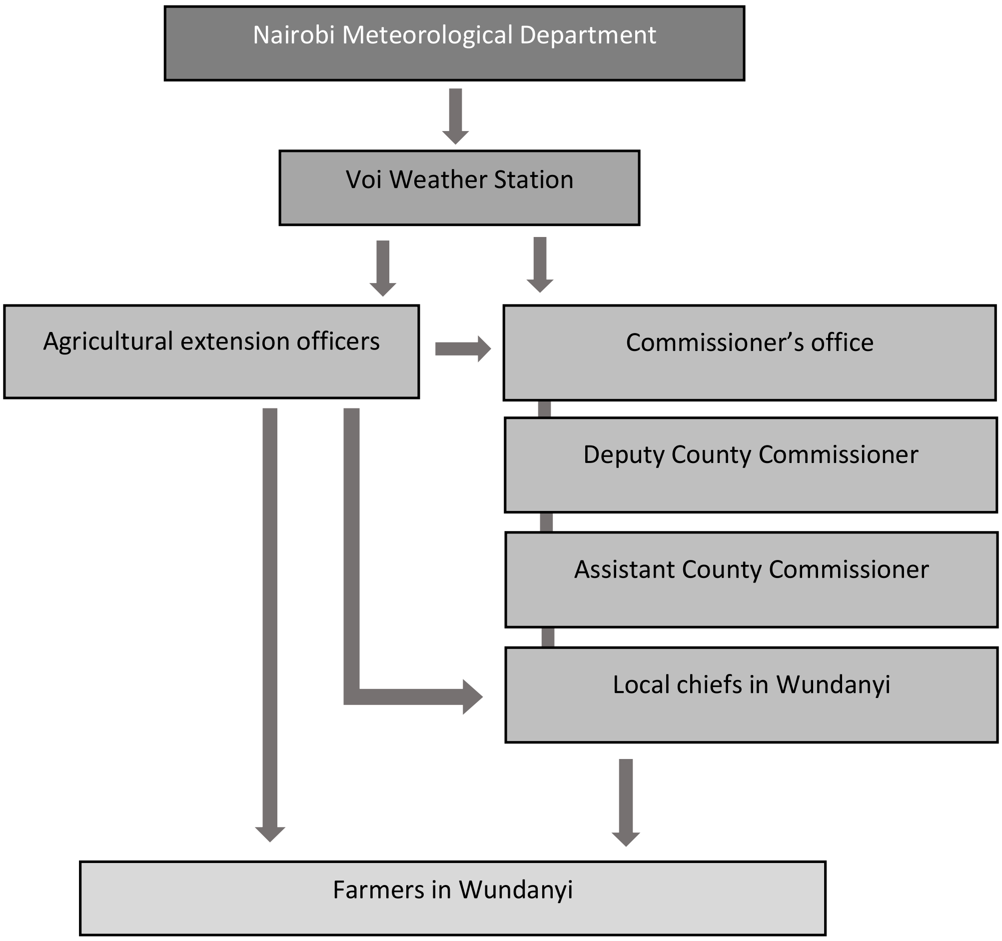

Figure 6 Illustrative example of the route of weather information to farmers

Voi Weather Station is also communicating straight to a number of farmers through email in Taita Taveta area and a few farmers also contact the station through email. However, none of the respondents stated they are using this possibility and it was highlighted that the farmers seeking information straight from the station are progressive farmers and have high education levels. It was also noted that the station does not get any feedback from the farmers they send the information apart from the few who initiatively contact them.

Community meetings such as barazas (meetings organized by the community leaders) were another source of information mentioned by thirteen (13) respondents. Weather related information was commonly about rainfall and whether it was the right time for preparing the land for planting together with other agriculture related information such as choosing the right types of seeds and disease and pest control and prevention as the same kind of information as from the extension officers. It is notable that the agricultural extension also took part and organized some of these meetings.

6.3.2 Climate change information

According to the data altogether sixteen (16) respondents had received some sort of information about climate change as a phenomenon through human-based information sources while fourteen (14) stated that they have not received information about the changing climate (Table 12.), however, it is notable that all of the respondents stated that they have noticed changes in climate (see more for Table 3.) The most common source of climate change information was trainings organized by the chiefs or an NGO (17 mentions together). Some farmers were not sure who was the organizer of the seminar or training. Only two (2) respondents stated that they have received information on climate change from the agricultural extension officers 15 of them reported that they have a connection to them (see more below). Also, neighbours, church, and school were mentioned (Table 13.)

Table 12 Number of human-based climate change information sources

	Farmer, N=30
0 sources	14
1 source	11
2 sources	4
3 sources	0
4 sources	1

Table 13 Human-based climate change information sources

	f (N=16)
Chief's barazas	9
NGO training or seminar	8
Agricultural extension officers	2*
Neighbours / relatives	2
Church	1
School	1

*Only two (2) respondents reported receiving climate change information from the agricultural extension officers, however, fifteen (15) of the interviewed farmers had been in contact to the officers either through household visits of in chiefs' barazas and received information on choosing the certain crop type, pest control counselling or any other agricultural guidance (see more in 6.3.2). It is assumed that these two respondents who reported receiving information on climate change received information on a more general basis as well as counselling on adaptation, while the others in contact with the officers had received information that is directly concerned with agricultural practices and did not regard it as climate change information. The relation between weather, climate and these processes more in detail in the conclusions.

The most common information respondents gained from the climate change information sources was advice to change crop type for more drought resistant types and especially shifting away from planting only maize was encouraged (14 mentions). The second common was an encouragement to plant for more trees and stay away from cutting trees and forests (7 mentions). Four (4) mentions were about environmental conservation especially in water catchment areas, one (1) mention was about better planning in agricultural practices as timing and choosing the right crops and one on rainwater harvesting (Table 14: Table 15.)

Table 14 Received information content from human-based climate change information sources

	f (N=16)
Change in crop/seeds (for more drought resistant/early maturing)	14
Tree planting and forest restoration	7
Environmental conservation such as in catchment areas	4
Better planning in agricultural practices	1
Rainwater harvesting	1

Table 15 Quotations on climate change information

"It (community meeting*) was about the changing climate and changing environment and they are giving advice on how to adapt to these changes, they told us to do tree planting, forest restoration, conservation of catchment areas as we should not cultivate on those areas"* -Farmer, 52 years *"... we are also told we should put more effort on rainwater harvesting and that we are trying to do, to plant varieties that require less rain, in most cases if we plant varieties that require a lot of rain they don't mature, so we have to do varieties that are more suitable for these circumstances, also trees for agroforestry like macadamia."* -Farmer, 50 years *"Information is important. We have been able to do more farming, we get more from the farm. Planting a long time ago was not organized but now we have learned how to organize planting, we have learned that"* – Farmer, 54 years

6.3.1 Local weather knowledge

Local traditional knowledge is one way of predicting weather and especially upcoming rain. According to the data twenty-six (26) respondents stated that they use traditional ways to predict rain. Four (4) respondents stated that they rely on calendar months only, as a knowledge on the right planting seasons. One of those four respondents stated being aware of the methods but claimed that they do not work anymore; three stated that they are not aware of the traditions at all (Table 16.)

Table 16 Traditional knowledge

	Farmers, N=30
Using traditional knowledge	26
Not using traditional knowledge	4

The data revealed several (meteorological, biological and astronomical) indicators in the environment that the respondents use to predict rain season. A common method was to look for local trees, such as jacaranda, and when they drop the leaves and start producing new leaves, or making flowers, it is said that the rain season is close to a start. Secondly, it was common to look for animals and certain behaviour or appearance. Appearance of red safari ants, certain birds, butterflies, and termites were all mentioned as indicators. Additionally, livestock running around and raising tails as well as crooking of frogs and toads were mentioned. Respondents also stated they look for clouds and dark clouds are an indication of the rain. Also, strong wind, high temperature, and dew were seen as signs of upcoming rain. Few respondents stated they look at the moon and its appearance (Table 17.)

It is notable that all respondents were aware of the planting seasons of crops as well as long and short rain period and scheduled their agricultural practices also according to the calendar.

Table 17 Traditional indicators for rain season

	f (N=26)		f (N=26)
Trees	19	High temperature	3
Clouds	7	Moon	3
Safari ants	6	Wind	3
Livestock running	5	Termites	2
Frogs	5	Butterflies	2
Birds	4	Dew	1

Trees were absolutely the most common way to predict the weather as well as the safari ants and were known by both young and older farmers (Table 18.)

Table 18 Quotations on traditional weather knowledge

"There are some plants and trees which show, they flower. Like the jacaranda tree, by the time of the rain, the tree drops the leaves and gets new ones. After two or three days it will rain when the new leaves start to shoot." -Farmer, 24 years *"Once I see the safari ants, the red ones, automatically I know the rain is about to come because those ants don't come unless the rain is almost coming."* – Farmer, 61 years

All of the respondents who were aware of the traditional weather knowledge stated that they had received this information from their parents and grandparents, hence it goes from generation to generation. Also, they indicated that these ways to predict rain is reliable since it is something people have done for long and it is something they can experience with their own eyes. Generally, the data indicated that the respondents use the knowledge of the seasons for timing when to be aware of the signs in the environment, i.e. they combine the knowledge of the seasons and the natural indicators. The traditional weather prediction methods were also seen as location-specific since the observation takes place where the information is needed and is for that area. This as a comparison for the scientific weather forecasts which the respondents claimed being not location-specific. The general statement was that there might be a forecast for rain but then the rain takes place somewhere else and not in Wundanyi.

According to the expert interviews, the agricultural extension officers also share traditional knowledge-based information. It was seen as reliable since it is a result of generations' experience and it is location-specific. It was also stated that some of the agriculture extension officers rely more on the traditional knowledge and encourage farmers to make and make use of their own observations. All respondents stated that they have received traditional knowledge from their parents and grandparents, but it was brought out that such knowledge is available also through certain youth clubs and groups where the agricultural extension officers visit to train them.

When talking about traditional knowledge, it was brought up both during the household interview as well as the expert interviews, that people might link traditional knowledge to traditional ceremonies and rituals that are for speeding up the upcoming rainfall. For example, two of the respondents mentioned a ritual where the elders gathered together to perform a ritual and also ancient drink was used for such purposes. One respondent stated that since those rituals are no longer performed it was affected the weather and the frequency of the rainfall. Additionally, traditional knowledge can be linked to witchcraft which potentially can make people unwilling to deal with it. However, there was no any indication that the indicators used by the respondents were considered as such. Nevertheless, it is worth taking into consideration that when talking about traditional knowledge with the interviewees it is worthwhile to emphasize the exact definition of traditional knowledge.

6.3.2 Social networks in information dissemination

Information regarding weather and climate is shared through several networks/forums. Most of the respondents, eleven (11), had one network available for sharing and receiving any weather and climate information. The second common was having two (2) networks available by seven (7) respondents. Six (6) respondents had three networks and three (3) respondents reported four networks. One (1) respondent had six networks (Table 19.)

Table 19 Number of information sharing forums of the respondents

	Farmers, N=30
No networks	2
One network	11
Two networks	7
Three networks	6
Four networks	3
Five networks	0
Six networks	1

Table 20 Social networks for information dissemination

	f (N=28)
Neighbours / fellow farmers	19
Agricultural extension officers	15
Chiefs' barazas	15
Relatives and family members outside the household	3
School	1
Farmer groups	5
Church	3

Sharing information with neighbouring farmers was the most common with nineteen (19) mentions. Barazas and other community meetings were another forum with fifteen (15) mentions, agricultural extension officers fifteen (15) farmer mentions, farmer groups with five (5) mentions and church with (3) mentions. Lastly, relatives outside the household were mentioned three (3) times and school one (1) time (Table 20.). Information shared was generally weather observations and received forecasts as well as the information received from potential trainings and from extension officers. Commonly, the respondents stated that those who shared information with their neighbours shared any kind of information. From barazas respondents received information about weather and climate change, they also had a possibility to ask questions and communicate with other farmers. Farmer groups which are a group of farmers cooperating in agriculture were another good way to share and received any information, observations and also ideas regarding farming practices. Churches were also good forums to meet other farmers in the area and give a possibility to share any information.

Although the majority of the respondents stated that they share information at least with their neighbours, there were three (3) respondents who just stayed by themselves and were not that much in connection with other people at least in terms of agricultural issues. This was seconded also during the expert interviews, that one challenge is that there are several farmers in Wundanyi who do not take part in any meetings or trainings and do not contact the agricultural extension officers and hence it is also difficult for them to locate them. However, although this kind of farmers was a minority in this research's sampling there were few who did not communicate much with their neighbours while most of the respondents stated that they communicate a lot with their neighbours and fellow farmers in the area (Table 21.)

Table 21 Quotations on sharing information

"We don't really discuss but I can see what my neighbour is doing but we don't discuss." -Farmer 70 years *"Yes, we share, and I get information from others. I pass information for my neighbours and in the chief's barazas, we meet in villages, we meet maybe once a month, we discuss what to do and so forth."* -Farmer, 61 years *"Yes, we share, normally it is the children who notice the* (safari) *ants so we often talk about it also with other people"* -Farmer, 34 years

Respondents indicated that the agricultural extension officers were a good source of information if they were available and they offered also other agriculture related guidance. Responses regarding the extension officers varied among the respondents. Eleven (11) respondents indicated that they were regularly visited by the extension officers and four (4) stated that they meet extension officers in community meetings. Nonetheless, eight (8) stated that the extension offices have never visited their homestead and seven (7) stated that they used to visit years ago but not anymore (Table 22.) Although expert interviews with two agricultural extension officers indicated that farmers have a possibility to contact the extension officers through mobile phones, only of the respondents stated doing do. Those respondents who are regularly in connection with the agricultural extension officers, stated that they receive information on upcoming weather, mainly rainfall, and on choosing on the right type of seeds as well as pest and disease prevention and control.

During the interviews, it was mentioned by one person that the services of the agricultural extension officers are demand-driven and chargeable and therefore not accessible for everybody. No other indications on this were made.

Table 22 Availability of agricultural extension services through extension officers

Farmers, N=30	
Contact (N=15)	No contact (N=15)
Household visits (11)	Have never visited (8)
Chiefs' barazas / other meetings (4)	Used to visit but not anymore (7)

As stated above, the respondents had very varying experiences regarding the agricultural extension officers. Part of the respondents felt the contribution from them as an essential part of their success in agricultural production. Other experiences were the opposite when some of the respondents stated they did not have any kind of connection to the officers (Table 23.)

Table 23 Quotations on agricultural extension services

*"Of course, they (*agricultural extension officers*) help us a lot. We know when to prepare the shamba (*farm*). We get information from the officers and we start preparing. ...they know that in two months we will have rain or we won't."* -Farmer, 51 years *"When I was young the officers used to visit but these days they don't come here"* -Farmer, 50 years

Agricultural extension officers share information on climate change through community meetings/barazas and churches to mention a few. Such information, according to the expert interviews, included adaptation methods and ways to decrease losses due to climate change. For example, there are technological examples such as so-called CA, conservation agriculture, through which very little disturbance is done to the soil so the roots of grass maintain the soil's ability to absorb water. There are also certain species that are more suitable for the changes such as sweet potato which is ready within three months, indigenous crops such as cassava and local legumes such as cow peas. These types of crops were also said to be healthier, more nutritious and they do not need pesticides as maize, for example. But again, it was said that people are hesitant to shift to crops that are not that familiar to them. Therefore, training on maize related challenges is given such as regarding pest control.

According to the interviews most of the respondents who attended barazas, other community meetings, farmer group meetings, church meetings, met neighbours and relatives and had connection with agricultural extension officers, stated that the communication on weather was mostly dialogical, meaning that they had an opportunity to ask questions and stated that the information is communicated for them rather than just given as it is. This was seconded by the expert interviews that the farmers have always an opportunity to ask questions and share ideas, however, in some cases, only a few decide to do so. This varies between the areas. It was also mentioned that the information is not only given as such but sometimes through traditional drums and dances as well as through actual demonstrations.

Figure 7 gives an illustrative example of a farmer's social networks for sharing weather and climate change information. Components such as neighbours, relatives and farmer group members allow changing of information as well as chiefs' barazas where it is possible to meet other farmers and also receive information from the chiefs and from the agricultural extension officers who can be available also outside the meetings. Arrows in the figure represent the direction of information in communication routes.

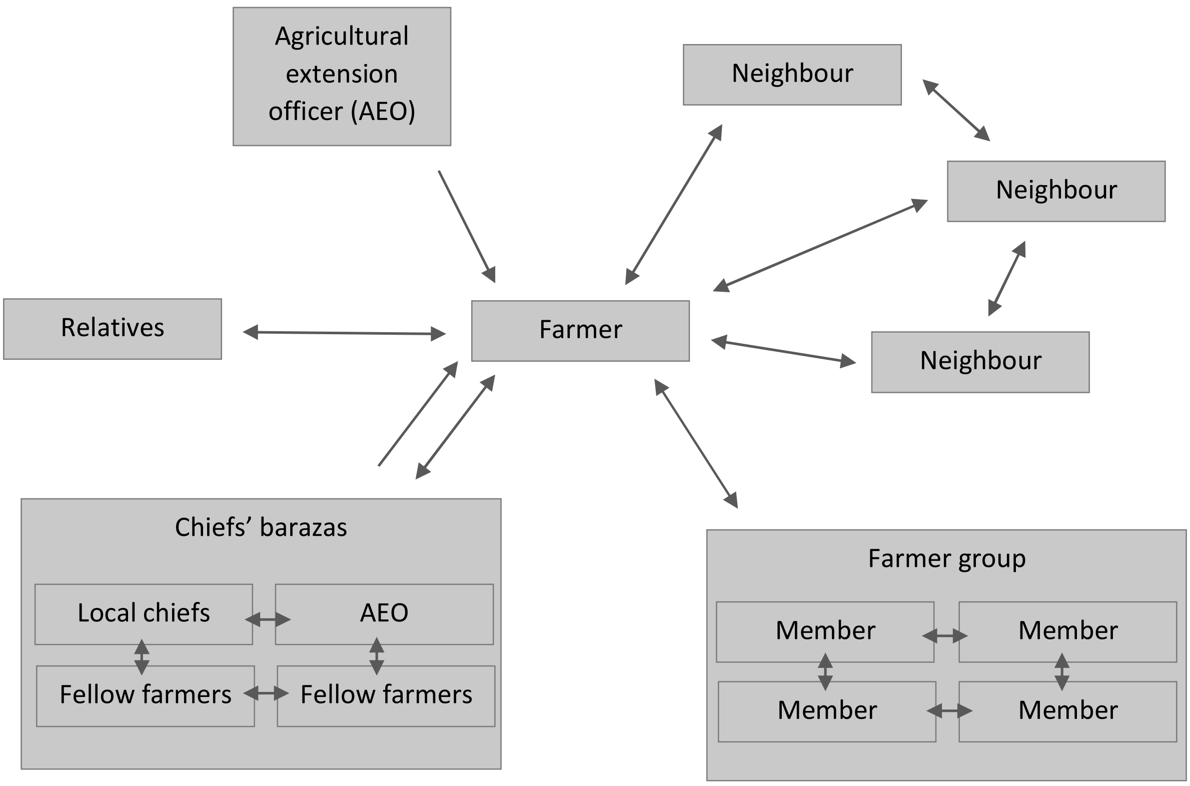

Figure 7 Illustrative example of a farmer's social networks

Fourteen (14) farmers reported that in a need of any weather-related information there is no one they can contact and they just rely on the information sources they have at that time available, for example, radio or their own senses and observations. All those farmers (4) who did not have any social networks for weather, climate and agricultural issues belonged to this group. Additionally, there were farmers with one or two networks and two (2) farmers with three networks but still felt unable to seek the information they need.

Although most of the respondents have at least one information sharing forum, it was mentioned during the expert interviews that there are not enough forums for farmers to discuss weather, climate and agriculture related issues. However, half of the respondents stated that they attend chiefs' barazas where such issues are discussed but there are no forums that are exclusively for agricultural issues. It was also noted that not every farmer is willing or able to attend barazas, and not everybody who attends is willing to share the information with others when returning home. The reason was said to be the fact that they felt they were not in a position to share information with a person who was not willing to attend by him/herself.

6.4 Application of weather and climate information services and traditional knowledge

In climate change adaptation, adequate information on weather and climate is essential. Adequacy of information can be measured through its utilization and received benefits. This section focuses on the respondents' ability to utilize the information they have received through ICT- and human-based sources.

6.4.1 Application of weather information

Most of the respondents who had access to weather forecasts stated that they either use that information in planning agricultural practices (13), virtually preparing the land for planting in the right time before the rain or that they do not use that information at all or not more than for general interest (12). Two (2) respondents stated that they use the information in planning other daily practices such as collecting firewood or marketing (Table 24.)

Table 24 Application of weather forecasts

	Farmers, N=27
In agricultural planning	13
For general interest / do not utilize	12
In other chores	2

However, although most of the respondents had access to official weather forecast announcements and approximately half of them stated that they utilize them in agricultural practices, all respondents stated that the forecasts are more or less unreliable. Most of them gave the same example that the announcement may predict rain but then there will not be rain. A common indication was that the predictions are not locally accurate (Table 25.)

Table 25 Quotations on utilizing weather forecasts

“Sometimes they fail so they are not accurate. Sometimes when they say it is going to rain it might not rain, it rains somewhere else.” -Farmer, 60 years
“Since the daily forecasts from the radio are not very reliable, I rarely rely on those, I don’t have much trust in them, they have a lot of conflicts.” -Farmer, 52 years
“They may say that rain is coming and then it fails so we are just waiting and continue with our lives.” - Farmer, 39 years
“Sometimes they are not sure so they don’t always know. Only God knows. Like, know we are expecting rain so we are depending on God.” -Farmer, 67 years

Weather information from other people was a mixture of official forecasts and people’s own observation, hence the information from such sources was more extensively utilized. Since the official rain predictions were regarded as rather unreliable respondents tended to use several information sources, information from ICT- and human-based sources as well as traditional knowledge and balance between them. The majority of the respondents (26) stated they use traditional knowledge; hence, it is significantly more common than utilizing official weather predictions. Also, the expert interview seconded that the farmers tend to balance between the given information and if the scientific forecasts and the traditional predictions disagree, they regard the traditions more reliable. However, most of the respondents also stated that they are open for any information given and could see them utilizing scientific information as long as they can prove it reliable by themselves. Hence, there were no indications of general doubts against scientific information, but it would need a strong empirical realization.

6.4.2 Application of climate change information

From the twenty-one (21) respondents who had received information regarding climate change all claimed that they have benefitted from such information and eleven (11) of them were able to explain which way. Eight (8) respondents stated that they have gained better yield after receiving information on climate change. Practically this was information was on choosing the right kind of crop type and seeds such as early maturing seeds and drought resistant crop types as well as crop diversification. Three (3) stated that they believe that there will be more fresh air and adequate rainfall if they plant trees (Table 26.) All nine (9) respondents, excluding one (1), who had not received information on climate change stated they would see such information useful.

Table 26 Utilization and benefits of climate change information

	Farmers, N=11
Better crop through a change in crop type	8
Potential fresh air and return of adequate rainfall through planting trees	3

According to the expert interviews, it was indicated that although farmers had information on the upcoming rain they might not necessarily act according to it but are more used to their old habits. For example, many actors such as the agricultural officers and NGOs working in the area are promoting shifting from maize to more drought resistant crops but farmers are hesitant to shift regardless of poor rainfall predictions.

7 Conclusions and discussion

This chapter draws conclusions from the research results and reflects them to the theories presented in the theoretical framework. First it considers the adequacy of WCIS for the farmers in Wundanyi; second, it discusses the importance of social networks in WCIS; third, it explains the role of agricultural extension services; fourth, acknowledges the importance of traditional weather knowledge; and fifth, considers climate change adaptation capacity. Finally, it concludes on the methodological consideration.

7.1 Adequacy of weather and climate information services

It is clear that all the farmers are in the reach of weather and climate information services of some sort. Even those who did not have any social networks in use had access to at least one of the ICT information sources, and those who did not have any ICT information sources had at least one social network. Thus, no one of the studied informants was completely excluded from WCIS, ICT-based and human-based information sources. However, farmers' experiences on the available services varied.

If considering the access theory by Ribot & Peluso (2003) WCIS does not include any aspects of unlawfulness since the used WCIS sources mentioned during the research process were all legal, meaning that any information was not obtained through illegal manners. Enabling mechanisms for access information were technical devices and somewhat also monetary assets were needed to purchase them. When gaining access to information, as knowledge, it enables a person's access to immaterial resources when gaining new skills. Access to immaterial resources, information, knowledge or skills, can be based on social networks, such as membership in certain communities or groups or friendship. As was seen in the results, social networks play a significant role in WCIS in Wundanyi. Farmers are surrounded by social networks where information is available formally and informally. Most of the respondents stated that they share information for example with their neighbors which require some level of friendship or trust (see more in 7.2).

Regarding the role of radio as an information source in WCIS, the results in this research are partly in line with the existing literature (e.g. Vaughan et al. 2017). Also, the informants in this research considered radio as the best source of weather and climate information due to easy availability, affordability, and usability. However, the informants considered the information from radio not very useful for them while, for example, according to Clarkson et al (2018) and Manfre & Nordehn (2013) farmers in Africa generally appreciate the information from the radio. The majority of the target farmers in Wundanyi had a radio and they reported receiving weather information through it, but mostly daily weather forecasts, which were not regarded as useful in agricultural practices. Daily forecasts were considered unreliable and therefore did not offer any information that could be utilized. Regarding information on climate change, radio and other ICT-based sources did not pay any significant role. Regarding other ICT-based sources, it is rather surprising that although mobile and internet coverage in Africa, and especially in Kenya, are widely developed and mobiles are used for numerous purposes, phones did not play a significant role in WCIS among the respondents of this research. For example, making payments through phones is common in Kenya so the use of phones is commonly familiar.

Regarding human-based information sources, they had significantly more meaning for the target farmers in this research. Most of the target farmers had at least one social network, only three target farmers were separated from any networks. Information from human-based sources was both weather and climate information. Farmers received information on upcoming rainfall and counselling on right crop types according to the expected rain. Sources that first hand offered weather and climate information were agricultural extension officers and chief's barazas. Both were reported offering timely information on rainfall and on required procedures accordingly.

Other human sources of weather and climate information were informal social relations within people's own social networks but also trainings and seminars were attended by a small group of the respondents. From those farmers who had reported that have benefited climate change information, all of them had received such information through human-based information sources, as their social networks.

While ICT sources offered mainly daily forecasts, human-based sources offered information mainly on the rainfall, hence it can be defined as seasonal forecasts. This is supported by Vaughan et al. (2017) who state that daily forecasts are better available than seasonal ones, however, Vaughan et al. also claim that from different WCIS user groups farmers most likely use daily forecasts which contradicts with the results of this research. Radio among the respondents is widely available and offers daily information while to get seasonal information one must interact with people.

Most of the farmers who had received information on climate change reported that the information was mainly about choosing the right types of crop type that would be more suitable for the present conditions. Part of the respondents were grateful for the received information and as according to the results eight respondents stated they have benefited from the new types of crop. This indicates that the available information concerning crop type for the farmers in Wundanyi supports the adaptation to climate change in the area. There were however indications on hesitations on making changes in crop and several times during the research process, especially the expert interviews, brought out the status of maize as crop.

Vaughan et al. (2017) have studied the use of WCIS and the results are in line with this research. They claim that farmers use information from WCIS is choosing the right crop or field, in timing agricultural processes, conservation of water and stocking. Target farmers reported similar uses as in timing activities according to the expected rainfall and in choosing the right type of crop.

There is evidence (e.g. Vaughan et al 2017; Yeboah 2017) that due to climate change induced extreme weather events, farmers are more in need of extreme weather warnings, such as drought and heavy rainfall warnings. The target farmers of this research did not mention they would have received such information. Although it is possible that such information is available, for example through agricultural extension offices who receive timely weather information. Additionally, regarding heavy rainfall, only one interviewee reported heavy rainfall as a sign of climate change. Drought was a more commonly observed indication of climate change but there was no evidence on specific warnings on drought. However, it was commonly reported that, for example, agricultural extension officers update farmers on the onset of rain so it could be expected that at least some farmers get information on drought if rainfall is significantly late.

If looking at the requirements for effective and adequate climate change information by WRI et al. (2011), the available climate change information in Wundanyi is somewhat user-driven since it requires the person to interact with other people or to attend chief's barazas or trainings and it corresponds with the challenges the farmers have faced. The information is also applicable since it was rather easily used in agriculture and seemed that the only hindrance was farmers' unwillingness to shift to other crop types than what they are used to. There was no evidence that changing crop type would, for example, bring any additional costs for the target farmers. Information that mainly comes from the agricultural extension officers can be regarded as up to date information since they regularly receive information from various sources. It also corresponds with the climatic changes in that specific location. However, the information does not reach every farmer in Wundanyi. Although the small group of farmers who did not receive any information on climate change was a minority in the sample of this research, it brings out the fact that there are farmers who are excluded from such information and who therefore do not have assets to cope with the climatic changes. This in spite that the information is brought to their location and to the social groups using their own language and communicative methods.

From the farmers' perspective, Murphy's (1993) qualifications for good weather forecasts, especially quality and value are meaningful. Daily weather forecasts from ICT sources received by the target farmers were considered as unreliable and not local specific, hence they do not represent a forecast with high quality. Consequently, they do not have much value for the farmers since they are aware of the low reliability of the forecasts. Seasonal forecasts from human-based information sources, however, present a higher level of quality since weather related information was regarded as useful for the farmers. This leads to a higher value of the forecasts since it can be utilized and is expected to bring benefits.

Credibility, as one of the constraints to forecasts effectiveness defined by Patt & Gwata (2002), is higher with the information coming from the human-based sources and, also, from the traditional knowledge. Since daily weather forecasts from ICT based sources lack in reliability, target farmers tended to have more reliability towards traditional weather knowledge and information coming from the human-based sources. Unreliability seemed to be the main reason for not using the scientific information from ICT sources and there were no indications that target farmers would have doubts about scientific information in general. Hence, there do not seem to be legitimacy issues as such with the weather forecasts. Challenges with scale have been brought out since especially the daily weather forecasts are not local specific and also other information is affected by it because, for example, there is no weather data produced in Wundanyi. Therefore, creating specific forecasts is challenging. Regarding cognitive constraints, there did not seem to be challenges in understanding any of the received information. There did not seem to be procedural constraints either, as there was not anything in the current agricultural practices that would prevent using any new information. Available weather forecasts included mainly information on rainfall which is essential for the farmers, it that sense they provided enough information.

Results did not reveal significant connections with gender, age, education level or size of the household and the access and use of WCIS. The younger half of the male respondents seem to have slightly more social networks than females and also did respondents who had relatively large families, more than five members. Additionally, as was noted in the results, radio as an information source was slightly more popular among the elder farmers. However, the limitations of data and qualitative nature of this research cannot offer fully reliable statistical information on these factors. As the literature has reported that men and women differ in access to WCIS, larger research data from Wundanyi would be needed for drawing reliable information.

7.2 Significance of social networks

Compared to ICT based information sources, human-based sources include the aspect of human interaction which allows communicating the information rather than offering it such. Hansen et al. (2019) pointed out the usefulness of participatory communication which activates the receiver of the information, hence creating the nature of communication rather than dissemination. Many target farmers indicated that the human-based information sources generally included a dialogical aspect as the agricultural extension officers, chiefs' barazas, etc. offered an opportunity to ask questions and clarification and discuss generally. Due to this dialogical aspect and since the human-based sources seemed to be available regularly, the farmers are forced to process the information experimentally and hence able to learn new ways of thinking. That will potentially lead to understanding and obtaining the information.

When considering new information especially on climate change, the theory of diffusion of innovation by Rogers (1995) can be utilized. As has been brought up several times during the research process, especially by the expert interviews, farmers in Wundanyi tend to rely on conventional maize and some farmers are hesitant to adopt new crop types. Alternative crops can be seen as innovations since they potentially are new to the farmers. Without detailed research on the adoption of specific crops, it is difficult to get a comprehensive understanding of the diffusion process but in this case, it can give a general overview of the present situation. Part of the farmers in Wundanyi is using new crop types which indicates that at least the innovators in that social group have adopted the new information. Since there are views that the unwillingness to adopt new species is a challenge it could indicate that the information has not reached the late majority yet, the early majority perhaps.

As has been pointed out, the way of communication is an essential part of disseminating information and therefore an important part of the diffusion theory. According to Rogers, face to face communication is potentially more efficient way to disseminate information than through for example media and in this research, respondents received climate change information mainly through human-based sources. Rogers claims that communication is more effective if the persons have similarities such as beliefs and, in this research, considered individuals have the same livelihood and perhaps the same income level, and are perhaps staying in the same location and are part of the same social group. These factors enable better communication and dissemination of information. Time is another important aspect and from the target farmers, there are those who are already implementing the adopted knowledge and potentially sharing the information for other, those who are aware of the new more suitable crop types but are still hesitant to make the decision and those who are not in the reach of the information. What comes to the innovation-decision, it could be said that the decision on shifting to new crop types is more optional decisions than decisions made as a result of external influence. Making a change in crop type to get better yield is more self-driven and due to decision-makers needs than due to somebody else's will.

Regarding Roger's (1995) and Goss' (1979) criticism of the diffusion of innovation theory, it is worth considering that new weather and climate information can bring also other than positive outcomes for the farmer. Although it is very likely that adopting new adaptation measures, it will enhance farmers' resilience to climate change, incorrect use of new practices or using not timely information may lead to negative impacts. Also, if a farmer is excluded from any social networks and therefore not receiving any information, it cannot be assumed that it is due to the person's conscious choice but can be a result of various factors, such as disabilities. The source of the information has a meaningful role since in human-based sources the way information is communicated affects the adoption of it. Target farmers indicated that the information from human-based sources is communicated rather than just disseminated. Additionally, since not all of the farmers have adopted adaptation measures, it is possible that those who are not, are facing or will face challenges when other farmers have advantages in crop markets, for instance. Goss had observed that the farmers the most in need had benefited relatively less from development projects, and it is possible also in Wundanyi that the important weather and climate information do not reach those who lack in assets the most to cope in the changing climate.

It is evident that social networks play an essential role in weather and climate information dissemination. Receiving both scientific and traditional information from various sources, being able to discuss with other farmers and experts together with farmer's own observations creates a toolbox of knowledge and skills for farmers to cope with the changes in climate. Social networks with other farmers create also a possibility for peer support and to share experiences. It is, however, worth noting that the social structure and social networks are both locally specific and there are also differences between individuals. Therefore, it is not evident that the results regarding them could be generalized to other societies.

7.3 Role of agricultural extension services

Agricultural extension officers play an important role in WCIS in Wundanyi. As was seen in the results, half of the target farmers had a regular connection to them either through household visits or in chiefs' barazas. Information from the officers was regarded as important and beneficial for all farmers. Agricultural extension officers are also together with the chiefs the actors who bring new timely information to the farmers. From another perspective, the other half of the target farmers did not have any connection with them. It is tough possible that the farmer attends chiefs' baraza where the officer is present, but the farmer is just not aware of it. The officers work closely with the local administration. As the national ratio between agricultural extension officers in 2012 was approximately 1 officer per 1000 farmers, it is not surprising that household visits to every farmer are not possible. In some areas, officers have their own farmer groups and the officer is available through phone and in group meetings.

Agricultural extension officers, as was already mentioned above, can offer timely information. As their work concentrates exclusively on agriculture, they provide seasonal forecasts with rainfall predictions that are crucial for the farmers. As they are able to offer information on a specific subject in a time the information is needed by the farmers, they are however, depending on the information that is offered for them and cannot, therefore, guarantee the certainty of the information. As has been brought out, producing prediction specifically for Wundanyi is challenging and the predictions are often high in uncertainty.

These days when communication technology is developing fast in Africa, there is great potential for keeping contact with a large number of people and possibly prioritize household visits accordingly. According to the National Agricultural Sector Extension Policy (GoK 2012: 17), it is assumed that the use of ICT in extension services will increase. In 2012, the use of ICT was considered low and the reasons were challenges in accessing and using ICT devices.

While agricultural extension services have previously been dominated by the public sector there has been a strong inclusion of other providers such as NGO based services. Four (4) respondents in this research reported that they have attended trainings or seminars organized by an NGO or a project. Seven others reported that they have attended training but were not sure who has the organizer. For example, also the chief's and the extension officers organize such events. This indicates that the services other than extension officers are available in Wundanyi at least for some farmers. Agricultural extension services are also shifting to more user driven services which would require more initiative from the farmers. This can be a challenge for those farmers who just stay by themselves and do not socialize much with other farmers in the area or especially with the agricultural extension officers.

Nevertheless, it is clear that for the target farmers the role of agricultural extension services is essential. They offer information about the rainfall, expected onset and volume that is regarded as the most important information for farmers to achieve efficient yield and minimize losses. In addition, they offer tools to cope with the changes in climate, such as alternative crop types and counselling on pest control as new pests appear along with the changing conditions. Such a combination of information is vital.

7.4 Importance of traditional knowledge

While target farmers use and look for science-based weather and climate change information, they also produce information by themselves. As was seen in the results almost all the respondents use traditional knowledge to schedule their agricultural practices. Several phenomena in nature were seen as meteorological, astrological and biological indicators of upcoming rain season. For example, the majority of the farmers mentioned keeping eye on certain trees and dropping, maturing of leaves or flowering. Such indications of rain were regarded as reliable in terms of certainty and, also, in terms of the source since traditional information was reported going from generation to generation. Therefore, there was a long experience of it in the families and additionally, it is site specific. Regarding certainty, a mutual comment was that traditional knowledge is accurate and can be trusted. Another important aspect of traditional knowledge is that it is easily available. If a farmer has the knowledge, he/she can easily utilize it to get the information since the evidence of upcoming rainfall is close in the surroundings of the household.

It does not require monetary inputs and is easy to understand. The results regarding the relations between traditional knowledge and scientific information, the results dealing with weather prediction agree with the existing literature. According to e.g. Coulibaly (2015), farmers in Malawi tended to rely more on traditional knowledge due to the same reason as the target farmers in Wundanyi: science-based weather forecasts lack in certainty and are not locally specific.

Traditional knowledge offers information on weather and specifically on the rainfall which is the information farmers need. In the context of climate change, people can make their own observations. Although farmers can make conclusions regarding the future climate based on their observations, to receive reliable information about future conditions, science-based information is needed to offer possible scenarios, and also information on adaptation methods. As the results indicated, according to both farmer and expert interviews, also agricultural extension officers utilize traditional knowledge in their work. They can use both types of information that can potentially complement each other. In terms of combining information, some target farmers stated that they do use both types of information but were not able to fully explain how. Generally, they looked both and, in a way, balanced between them leaning more on the traditional knowledge. However, as has been stated by Orlove et al (2010), traditional knowledge systems are empirical systems, not stable and can learn from other systems. As there seems to be well-grounded traditional knowledge system, it is possible that the system learns from the present scientific system and creates new ways to observe weather and climate and ways to utilize available information. As a conclusion regarding traditional knowledge, there is no need to see it as something that belongs to the past. At this moment, it is still valid and meets the needs of the farmers in terms of rainfall predictions that is crucial information and relied by most of the target farmers.

7.5 Opportunities in information and communication technology

As has been indicated several times during this research, radio is a device that is regularly owned by the target farmers due to its affordability and easy utilization but the information from the radio was not seen relevant. Nevertheless, there is great potential in ICT-based information sources. As was stated in the results, there have been weather and agriculture related radio programmes but due to limited funding, they are rarely made at the moment. Also, one national weather programme is possibly not broadcasted anymore.

In addition to the farmers, the expert interviews seconded that radio would be a good device to reach farmers. The downside of the radio is that just broadcasting a programme is very one-sided in nature of communication and lacks in a dialog when the information does not necessarily reach the target. However, as for example Hansen et al. (2019) who has emphasized the benefit of participatory methods, such a challenge is possible to overcome. Information can be put in a form of drama when it is brought closer to practice. Additionally, there are experiences in community listening groups that enable dialog between the farmers themselves to enhance learning. Listeners are also possible to take along to the actual broadcast through phone calls when they have the possibility to ask for clarification and ask for personalized information. There is a lot of this kind of experience in Africa (e.g. Hansen et al. 2019) and through, for example, local radio stations can provide locally specific information for a great number of people and participate listeners through phone calls, text messages, etc. According to the author's own experience, one example is from Zambia where local environmental organization has organized participatory radio shows with local stations as part of their climate resilience project in rural areas. Shows have been a great tool to reach people which has been indicated in the number of phone calls during the show and in requests to broadcast more shows.

Another ICT aspect that has been brought out several times is the use of mobile phones. The target farmers in this research did not generally see phones as a relative source of information. However, seemed like a phone, just like radio, is a commonly owned device and therefore there is potential also in phones, whether they are smartphones or conventional. Mobile phones are especially good for disseminating information that requires fast responses, for example, extreme weather warnings (Hansen et al. 2019). Among the farmers in Wundanyi, some of the agricultural extension officers use phones to keep in touch with their farmer groups and the officers have their own WhatsApp group with the Voi Weather Station which they use for receiving the seasonal forecasts they disseminate to the farmers. In that sense, there are already experiences in utilizing phones although the number of benefitting farmers is limited. It is rather possible that the use of ICT-based sources is increasing also among the target farmers along with the general development and due to the good experiences from other areas.

7.6 Aspects of climate change adaptation

Specialized information in weather and climate essential for climate change adaptation and especially important for subsistence farmers that rely on rainfall. The target farmers of this research have received information on adaptation methods but there are differences between farmers. The information received by the target farmers seemed to concentrate on alternative crop types such a drought resistant or fast maturing according to the expected rainfall as well as pest control and counselling on fertilizers. However, it is possible that there has been more diverse information, for example on livelihood diversification, but did not bring up during the interviews.

When looking at the classification of climate adaptation approaches by Dessai et al. (2005) and the third group, human development approaches which is an approach compiled by UNDP's Adaptation Policy Framework aim to reduce vulnerability, they can be observed in the context of target farmers of this research. The human development approach acknowledges climate change as a development problem and concentrates on the adaptive capacity in terms of fore example access to information and organizational arrangements. Climate scenarios are considered but focus on the short-term variability, as in this case, vulnerability to drought and irregular rainfall that are already experienced in Wundanyi. The steps in this approach include vulnerability assessment, framing future climate risks, adaptation strategy development and the actual adaptation process (UNDP 2004.) If simplified, in Wundanyi, the rainfall dependent subsistence farmers have been identified vulnerable for the impacts of climate change; future and present risks, increasing drought and unreliable rainfall pattern, are identified; strategies, for example, alternative crop types, to overcome such challenges have been created; and finally, these measures are being shared with the farmers through the agricultural extension officers for instance.

Additionally, regarding other adaptation approaches and options, adaptation in the context of this research can be seen aligning at least with the win-win option. Win-Win option potentially brings positive impacts even outside the climate induced effects (Willows & Connell 2003: 67). Being aware of and choosing different kinds of crop types might bring positive outcomes anyway. This approach could also be seen as a flexible option since the farmers can make decisions according to the climatic situation and the expected rainfall. If there is a prediction on erratic rainfall, they can choose other crops that they are normally using.

If looking at Kenya's National Adaptation Plan and the Climate Smart Agriculture Strategy, the adaptation information received by the target farmers is in line with the mentioned documents. Target farmers in Wundanyi received somewhat timely, accurate and reliable weather information if considering the information form human-based sources, especially from the agricultural extension services and chiefs' barazas. Choosing alternative drought resistant crop varieties was promoted but there was no information on the pest and disease resistance of those crops. Target farmers had challenges with, for example, fall armyworm but had received guidance on pest control. As was mentioned above, there were no mentions on livelihood diversification, but it is possible that it was just not brought up during the interviews. Only one respondent mentioned rainwater harvesting which in this context is slightly surprising since it is a common practice in Kenya. Only a small part of the land in Wundanyi has irrigation potential so rainwater harvesting could be another potential method for irrigation especially when looking at the prolonged dry periods. Also, agroforestry and conservation agriculture were mentioned in the expert interviews and according to that such methods are promoted in Wundanyi.

Although almost all of the target farmers in this research have received information on suitable adaptation methods there were framers who were excluded from social networks and hence did not have any information on how to cope with the changes. Additionally, if considering those farmers as the most vulnerable ones, it would be critical to reach them.

7.7 Future considerations of WCIS in the Taita Hills

If looking at the quality of available weather forecasts the main factor seemed to be the high unreliability which prevented farmers from relying on them. However, there are weather stations in the Taita Hills but whether not operating or not producing data specifically for KMS for forecasts production. Mapping the existing stations and possibly establishing cooperation between the operating parties and KMS could potentially lead to the utilization of the existing data and to improved forecasts. One aspect of weather forecasts in this study that was left with less attention was extreme weather events and related warnings. To get a fully comprehensive understanding of all available services it would require identifying availability and usage of extreme weather alerts.

Agricultural extension services in this study were mainly referred to as the government-based services but the sector of extension services is in a transition to multi-operating services including NGOs and the private sector. Therefore, it would be interesting to identify all the operating parties in the Taita Hills who can be regarded as part of the extension services. The interviewed farmers did mention NGOs and other institutions but named only a few. Some farmers were not certain who was the provider of the training or seminar. Mapping all the operating institutions in the area could offer a comprehensive view of the agricultural extension services and also provide tools for improving them. The educational content of the extension services in detail would be beneficial to study in order to fully understand if they offer, for example, a comprehensive selection of adaptation measures or is there something new that could be suitable for the area of the Taita Hills and for the farmers. This study did not bring out, for example, livelihood diversification as an adaptation method and it would be interesting to know what all the provided measures in detail are and if there is something that was just not mentioned by the interviewed farmers. This could potentially point out a need for the introduction of new potential measures.

One challenge brought out by this study was reaching the farmers that are isolated from the agricultural extension services and any other events and social groups from where they could receive information about climate change and adaptation. The interviewed extension officers seconded that reaching these farmers is difficult since it is a challenge to identify them in the first place. Cooperation between all operating institutions in the area including health care, any social services and churches could help in the identification of these vulnerable farmers. Also, carrying out a study on the social structures of the area and utilizing the strong local knowledge of the local people could potentially help in that effort.

Regarding adaptation, one significant factor was the role of maize. Farmers tended to be so adjusted to growing maize that shifting to other crops seemed to be a real challenge although it was said to bring benefits in the changing climate. For an average western consumer with a large selection of food items, reliance on one crop can seem as peculiar. It would be interesting to study people's perceptions of their reliance on maize in the Taita Hills which could potentially offer tools for more efficient adaptation education.

As was pointed out in the previous chapter there is a lot of potential in information and communication technology in improving WCIS. Since the sample size in this study was rather small it was not able to provide much information considering, for example, age and gender as factors in WCIS although literature did show evidence on that. It would be worthwhile to study especially how the youth use ICT and how such services could be improved to serve them better. Since children and the youth are the farmers in the future and since the ICT is developing around the globe and in Kenya it would be important to link the needs of the young people and the supply of ICT in the sector of agriculture. It was brought out in this study that elder farmers tended to use more the radio than younger farmers and although there was no indication that the youth were using mobile phones more, it seems to be common that the younger generation is more advanced with mobile phones. Even radio programmes could be listened to through phones. Production and improvement of services provided through mobile phones could be one aspect of the development of WCIS.

It is wished for that this study could support the development of WCIS is the Taita Hills and in Kenya by the identification of strengths and weaknesses of the present system. Also, by the identification of points of improvement and potential research subjects, for example, the ones mentioned above in this chapter which are all in the interests of the author of this study as well.

This study will be available online for anyone who has access to the internet and possibly in the library of the Taita Research Station of the University of Helsinki in Wundanyi.

7.8 Terminological and methodological considerations

When dealing with such abstract definitions as weather and climate it is worthwhile to pay attention to terminological aspects in this research. While weather is slightly easier to understand since it is something that can be observed through own senses, climate and climate change were somewhat more difficult to differentiate from the weather. Although there was an effort on finding out the farmers' perceptions on these terms and act accordingly, there is a possibility that the contradiction has affected the results. Additionally, weather and climate information do overlap and identifying specific points for one another might not be clear in every case. Results were however construed according to the author's best understanding and such challenges were regarded in the interview process.

Other terms that can have several definitions are family and household. As this was discussed shortly previously in this research, there are no clear definitions for them and perception on person's family might differ from that group of people who stay in the same household and are the core family, to the group of people with those who stay in the same household and those who are the same core family but stay elsewhere, and to the group of people who stay in the same household but consist of several core families. Also, it might differ how distant relatives are considered family and which relatives. Additionally, households can consist of several buildings and people can have different views that whether household covers everybody in the same plot or not.

There are some methodological considerations to take into account and the main points regarding this research are connected to the interview process. Firstly, the target informants represented the households and it cannot be secured that the person was aware of the information some other family members might possess. Second, a great part of the interviews was done through an interpreter and there is a risk that some information was left out when translating or some interpretation mistakes took place during the discussion. The translation was first the interpreter's interpretation of the information from Kitaita to English and then another translation from English according to the author's interpretation of the data. It is not uncommon for information getting lost in translation. Third, in addition to more technical translation errors, there is a possibility to a different understanding of terms and definitions which affects the data as was considered with the weather and climate definitions above. Fourth, informants might have several reasons to not give the requested information since some topics, for example income and education, might be too sensitive to be discussed with a third party, as well as activities of other people. Such interviews are dependent on the connection between the interviewer, interviewee, and interpreter and social factors play an important role in creating a positive and trustful atmosphere. Fifth, the results in this kind of research are dependent on the author's understanding on the data and ability to create suitable codes during the analyzing process and ability to find relevant causalities and connection between codes.

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